GROWTH AND DEVELOPMENT OF
FLORUNNER PEANUTS AS AFFECTED BY TEMPERATURE

By

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The Florunner variety of peanut (<u>Arachis hypogaea</u> L.) is largely
responsible for recent yield increases of peanuts in the southeastern
United States. This research was conducted to provide information on
temperature effects on the growth and development of the Florunner
variety and to gain growth analysis-simulation modeling input. Six-
teen temperature treatments at 32, 26, 20, and 17 C day and 26, 20,
14, and 11 C night temperature in factorial design were studied. The
plants were grown in temperature-controlled glasshouses at the Duke
University Phytotron of the Southeastern Plant Environment Laboratories
under natural light.

The length of five phenologic growth periods was studied. These
periods were: 1. germination; 2. vegetative; 3. flowering;
4. filling; 5. total period of growth and development. The plants
were germinated and grown to maturity or experiment cessation in their
respective temperature treatments. Day temperature effect was

consistently non-significant while night temperature was negatively and significantly correlated at $P<.0001$ in the first two periods only. For all periods, mean temperature was negatively and significantly correlated at $P<.0001$. As temperature decreased, the length of the first two periods increased. Total length of development through the vegetative period was 31 days for the 32/26 (day/night) and 26/26 treatments and 75 days for the 17/11 treatment.

A fundamental change in developmental patterns occurred in the flowering period. Flowering period length of the low temperature treatments was apparently controlled by vegetative growth factors. Flowering period length of the warmer treatments was controlled by the growth and development of pod load. The 17/11 treatment bloomed for a similar length of time as the 32/26 treatment.

Mainstem length was an indicator of the effect of temperature on plant growth habit. Both mean and day temperatures were positively and significantly correlated to height at $P<.003$ and night temperature was positively and significantly correlated at $P<.02$.

A photographic study was conducted to allow for visual comparison of treatment plants with the numerical results from various analyses. The study included: 1. representative plant comparisons at day 135 of the experiment; 2. representative, potted, final harvest plants; and 3. representative, depotted, inverted, final harvest plants.

Vegetative component dry weight measurements were: 1. total; 2. root; 3. stem; and 4. leaf. Reproductive measurements were: 1. total pod dry weight; 2. total pod number; 3. mature pod dry weight; 4. mature pod number; and 5. total reproductive dry weight. Analysis of variance showed all measurements to be significant at

P<.0001 for night temperature effect and day-night temperature inter-
action. Day temperature effect in some measurements had lower
significance or was non-significant. Most vegetative component
analyses had R^2 values surpassing .93 indicating a removal of most
non-treatment variation. Many reproductive component analyses had
R^2 values lower than those of the vegetative components.

Mature pod dry weight percentage of total pod dry weight indi-
cated that the Florunner variety yields an almost constant value of
90% mature pods over a wide range of temperatures. The mature pod
number percentage of total pod number did not remain constant. Data
from the 26/26 treatment indicated that the Florunner variety exhibits
thermoperiodicity. Constant temperatures tended to retard plant
growth and development. A day temperature lower than night increased
pod set and yield. The 17/26 and 20/26 treatments produced over one
and one-half times the pod numbers of any other treatment.

The effect of the day or night temperature groups on each night
or day temperature was varied. High day or night temperatures fre-
quently counteracted the negative effects of corresponding low night
or day temperatures. The effect of temperature is strong and
extremely complex. A better understanding of temperature effects
on peanuts is provided by the controlled conditions of this research.

INTRODUCTION

Yao (1973) has stated that the primary challenge presently facing mankind is the feeding of a rapidly growing world population. Land use must account for climatic hazards. More than ever before it has become necessary to place crops where they are best suited. Correct placement necessitates complete knowledge of a crop's requirements whether they be edaphic, physiographic, biotic, or climatic. An example of incorrect crop placement is noted by Yao (1973) in the East African Groundnut Scheme of the late 1940's that failed completely because climatic assessment had not been completed in the area. He reports that although temperature conditions are even more favorable for peanut production in central Tanzania than in the eastern United States' coastal plains, the rainfall regime is unfavorable for agriculture.

The total climatic effect upon a crop involves not only a study of the effect specific changes in a climatic factor, such as temperature, has upon the crop plant, but also requires a study of longterm changes in climate. Of concern to agriculturalists, McCloud (1977) states, is that the last ten thousand years (during which man developed agriculture) was one of the warmer periods of the past million years. These periods are rare, he says, and necessitate a look at weather-induced crop variability with a purpose of examining what effect future climate changes may have upon a crop.

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The peanut is a crop that is being cultivated in temperate regions like an annual crop. But, it possesses indeterminant growth and survives like a perennial in frost-free zones (Smith, 1954). The plant is a native of South America and its center of origin and one of its centers of diversification is along the Amazon river through Brazil, Bolivia, Paraguay, Uraguay and northern Argentina. The peanut's area of cultivation extends far beyond its tropical birthplace. With this expansion of cultivation the study of climatic factors affecting the crop is of primary interest to the agriculturalist.

Research Justification

In a study of weather-induced variability on the peanut crop, McCloud (1977) found that peanuts in Florida show less short-term variability than many other Florida crops. Peanuts are a stable crop and there is little evidence to suggest that the variability increases in recent years' higher yield levels. McCloud states that in Florida the yield per unit of land area of peanuts has increased over four times its 1948 level. The average yield of unshelled peanuts in 1978 was 3,870 kg/ha in Florida (Anonymous, 1979). Some farmers had yields that exceeded 5,500 kg/ha. These yields are far below the world record yield of 9,600 kg/ha found in Rhodesia with the variety Makulu Red (Dr. D. E. McCloud, personal communication; University of Florida, Gainesville, Florida).

It was the lower record yield of peanuts in Florida that prompted the undertaking of the study described in this dissertation. The record yield in Rhodesia occurred at an elevation of 1233 meters at 20° S latitude on a similar soil type to many U. S. peanut region

soils. It was therefore postulated that temperature might be an impor-
tant factor influencing yield at the elevation that the record yields
occurred. The higher elevation should exhibit a different temperature
regime than lower elevations, especially at night. Williams et al.
(1975) state that in Rhodesia peanut growth at different elevations
is greatly influenced by the mean temperature occurring at those
elevations.

Temperature has many effects on the peanut plant. Many of these
effects will be highlighted in the Review of Literature. Regardless
of the effects temperature has on the vegetative portion of the peanut
plant, it remains a fact that the final yield is determined by the
number of pods set per unit area. Duncan et al. (1978) have speculated
that in the evolution of the peanut, the rate of partitioning of assim-
ilates to the pods was related to survival in different environments.
Under less severe conditions, they concluded that plants producing
the most pods would have the advantage whereas in harsher environments
the plants that protected the leaves would be better able to survive.
Temperature is a major factor in causing environmental variation.

It is well known that temperature affects the developmental
and growth rates of crop plants. The exact effect upon the filling
rate or length of the filling period is related not only directly
to temperature, but indirectly as well through temperature effects
on the rest of the plant. Thomas and Raper (1978) concluded from
temperature work on soybeans that various plant organs (i. e., vegeta-
tive vs. reproductive) vie for available nutrients and photosynthate.
This competition is probably true for all crop plants. The work of

Duncan et al. (1978) on growth analysis and partitioning showed that selection for yield in peanuts has resulted in the development of peanut cultivars that partition more assimilate to the fruit.   Dr. W. G. Duncan (personal communication; University of Florida, Gainesville, Florida) has observed that little thought or effort has been devoted to ways of increasing the length of the filling period in any crop.

Experimental Objectives

The objectives of the research presented in this dissertation were to provide information on temperature effects on the growth and development of the Florunner variety of peanut and to gain growth analysis-simulation modeling input. Various plant components were measured in order to delineate differences in temperature treatments. In most cases no attempt has been made to explain differences found since the experiment was not designed for this purpose.

LITERATURE REVIEW

General

Van Dobben (1962) states that the division of dry matter over parts of the plant is as important as the total yield of plant material. An increase in yield--in reference to the part of the plant that is used--may be due to a shift in distribution of dry matter to the part of the plant used. It appears that more primitive peanut varieties continue to grow their tops when they reach full pod load, thereby reducing the final yield (Dr. W. G. Duncan, personal communication; University of Florida, Gainesville, Florida). Lower yielding varieties in use today often have greener and healthier leaves than the high yielding varieties, Dr. Duncan says. Final yield of specific organs is a result of the production and distribution of matter in subsequent phases of plant development, according to Van Dobben (1962). The distribution within each phase depends upon environmental factors. Specific and climatic fluctuations in growth rate are due to formative processes, especially the rate at which newly produced matter is converted to assimilating tissue. The distribution of matter in the plant is the key to the problem of the influence of temperature (Van Dobben, 1962).

A year after Van Dobben's work, De Beer (1963) stated that total growth of a plant can be considered to be the product of the growth of its component parts. The optimum temperature for each component

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may not be the same and each plant part affects the others. The
latter is in agreement with Van Dobben.

While each plant part may be affected differently by temperature,
the whole plant may vary in its reaction. Went (1957) has found that
there are almost as many reaction types of plants to climate as there
are plants that have been investigated. De Beer (1963), though, states
that closely related plants usually react to variations in climatic
factors in a similar way. While Bolhuis and De Groot (1959), in their
investigation on the effect of temperature on three varieties of peanut,
found no great difference between varieties, Dr. J. H. Williams (personal
communication; Crop Breeding Institute, Salisbury, Rhodesia) has found
genotype x environmental interactions. Some varieties were found to
be more adapted to sunny weather while others were more adapted to
cloudy conditions. He found some varieties responded better to higher
temperatures than others and some varieties were not as well adapted
to cool temperatures. No reasons for the differences were found. Cer-
tain macromutants studied by Carlson et al. (1975) produced more flowers
and pegs at cooler temperatures than the parent controls. They postulated
that it may be possible to use hybrid populations from macromutants
for selecting lines buffered to a range of environments.

The effect of temperature on the period until flowering differs
with variety according to Bolhuis and De Groot (1959) and Carlson
(1972). Chang in 1974 found an interaction of variety x temperature
significant at the 1% level for fertilized flower ratio, total number
of fertilized flowers, weight of dry seeds, and the weight of dry
pods.

Breeding techniques have created variation within plant species as shown by Carlson (1972) and Carlson et al. (1975). Carlson (1972) found that his peanut control reached maximum reproductive and vegetative development at high temperatures while the expression of breeding heterosis was best at low temperatures.

The literature shows the peanut plant to respond well to temperature according to Williams (1975). My literature search substantiates Williams' finding. There are cases, though, where authors state that there is no temperature effect upon the peanut. Jowett and Eriaka (1966) found no relationship between the yield of peanuts and climatic factors, specifically sunshine and rainfall in Uganda. Since both these climatic factors are closely related to temperature, it can be assumed that no effect for temperature would have been found. Nevertheless, Alegre (1957) grew a peanut variety common to Senegal at three temperature regimes and concluded that temperature is the most important factor in the growth and development of peanuts. One of the causes of the variation of data and disagreement of authors is that few of the early workers on temperature did their work under controlled environmental conditions (De Beer, 1963). Dr. J. H. Williams (personal communication; Crop Breeding Institute, Salisbury, Rhodesia) has found interpretation of analyses involving aspects of the environment to be complicated by the fact that few environmental factors vary independently from each other. And, due to this interrelationship between factors, it may be difficult to identify which factors of the environment are, by themselves, related to final yield. Variations in environmental conditions result in temperatures varying

around a mean. Therefore, he found that temperatures for different phases of crop growth were only able to vary independently within certain limits.

The problems encountered by Dr. Williams are common in the literature on temperature. De Beer (1963) stresses this point when he says that results and conclusions are only valid for circumstances under which experiments are carried out. In his work with various types of environmental growth chambers, rooms, and greenhouses, De Beer states that direct comparison of greenhouses with controlled rooms was difficult since the greenhouses in his work were not controlled. A report on controlled environment facilities issued in 1975 (Anonymous, 1975a) discusses at length the problems of comparing controlled environment data with that obtained from field research.

Temperature may be regarded as a decisive factor in normal plant growth (De Beer, 1963), but its influence is quite intricate since environmental factors do not act independently. That is, the effect of one factor may be different at various levels of another factor. The latter problem has prompted Fortanier (1957) to say that temperature investigations can only be conducted well when all other conditions are at an optimum.

In general, Fortanier (1957) says that tropical plants (which include the peanut) are characterized by high temperatures for optimum development. Went (1953), though, believes that this higher temperature optimum causes a smaller assimilation/disassimilation ratio and that this lower ratio may be why plants in the tropics often do not grow

as well as do plants in temperate regions. Fortanier (1957) states
in his review of literature that most authors prior to 1957 tried to
explain the influence of temperature using this ratio. Tempera-
ture controls many plant processes and questions regarding the optimum
day and night temperature, the length of the period that these tempera-
tures are in effect, and their relation with the growth of the peanut
remain unanswered (Fortanier, 1957). The latter is as true today as
it was in 1957. While the overall effect of temperature on the peanut
needs clarification, new varieties are constantly being produced
and the problems discussed earlier require new research to be conducted
regularly.

Spiertz (1974), in work with wheat, produced a source-sink model
to show the effects of temperature upon wheat plant growth. His model
also basically applies to the peanut plant. Temperature and light
exert a controlling effect upon photosynthetic area, net assimilation
rate, sink strength, sink size, and transport between the source
and the sink. The following literature review sections deal with
the effects of temperature upon the growth and development of the peanut
plant.

Heat Unit Approach

Many authors in the past have attempted to use heat units to explain
and model plant growth. In peanuts, much of this work has been under-
taken because there is a considerable amount of confusion among peanut
growers as to the optimum time for harvest, according to McCloud (1974).
He states that a reliable indicator of the point of maximum yield
would greatly ease the harvest decision-making process.

Most of the heat unit work with peanuts concerns the growth period from germination until flowering onset. Ono et al. (1974a) produced an "effective heat summation" that is required for first flowering. They integrated a daily mean temperature over 12 C. This summation showed the least variation among peanut plants sown at different times for the various heat unit methods tested. Cox and Martin (1974) studied two basic types of curvilinear response functions. The best estimate for time from planting to flowering was obtained with one of the curvilinear functions. In an attempt to account for variability between germination and 50% flowering, Emery et al. (1969) found the closest fit for the duration of this phase to be an index adjusted for a lower cardinal temperature of 13 C. They state that their data clearly demonstrate that heat units can be used to identify growth periods of the life cycle of peanut varieties. Furthermore, they say that whether or not heat units can be used to accurately estimate fruit maturation depends upon factors yet to be determined (such as the effect of water deficit). Attempts were being made in 1969 by Emery et al. (1969) to determine heat units for 50% flower to early fruit and early fruit to maturity. A planting date variable was used by Cox and Martin (1974) to get variable temperature data for the period from planting to flowering. They then related these data to maximum and minimum temperatures and attempted to predict better the length of the period by use of a mathematical equation. They felt that their equation would be more accurate than a linear heat unit system.

Other work, though, has been done on the complete life cycle of the peanut plant. Mills (1961, 1964) found that plant maturity

and development could be best predicted by accumulating heat units between two cardinal temperatures. The lower cardinal temperature is where no growth occurs and the upper temperature is an optimum after which growth slows or stops. The two temperatures that he used were 13 C and 24 C, respectively. Temperatures above 24 C had no additional effect on growth and though the mean temperature might continue to rise, growth would not show a corresponding increase.

At the time Mills' research was performed, he reports that no heat unit research had been conducted on peanuts. Mills' work was performed on peanut seedlings using constant temperatures under laboratory growth chamber conditions.

Gupton (1968) believes that Mills' work is not generally applicable because of the impossibility to extrapolate the cardinal temperatures for germination in growth chambers to the whole growing season. Extrapolation is exactly what Mills did. Mills did state, though, that his temperatures were only guides since extrapolation from chamber to field is difficult.

Williams (1975) found that his data were in accordance with Mills to the effect that the greater the proportion of the day when temperatures exceed the upper cardinal temperature limit, the greater the divergence between mean temperature and development. He states that this finding possibly explains Fortanier's (1957) conclusion that when the temperature range exceeds 20 C, the relationship between mean temperature and development disappears.

In an attempt to understand fruit formation, Ono and Ozaki (1974) produced an "effective heat summation" accumulated from a daily mean

temperature over 15 C. When this summation was higher than 450 in the pod stage, fruit development was affected by inner factors of the plant and not temperature. When lower, the development was affected mainly by air temperature. Valli (1965) used five biometerological factors to predict the maturity of peanut varieties. They were: 1. growing degree days; 2. effective heat units; 3. effective radiation; 4. actual langleys; 5. effective langleys. He concluded that effective langleys were the best single predictor of peanut maturity. These units consist of a combination measurement of temperature and light.

Though much research has been undertaken to use heat units or similar indices to measure plant maturity, there are major disadvantages to many of them. Wang (1960) has summarized five major disadvantages to the heat unit approach to plant response. Of his criticisms, the failure of many indices to take into account the shift in optimal temperatures during plant development or account for the fact that optimal day and night temperatures are strongly dependent upon light intensity are of primary importance. Valli (1965) made an attempt to alleviate these criticisms in his work.

Thermoperiodicity

Went (1944, 1945, 1948, 1953) introduced the term of thermoperiodicity to label plant response to cyclic variations in temperature. He found that the majority of species tested grew much better when subjected to a diurnal change in temperature. He came to the conclusion in his work in 1953 that temperature, as a growth factor, always

has the greatest influence and that a night temperature a few degrees cooler than the day temperature gives better growth results than does a constant temperature. Chouard (1951) uses the term thermoperiodicity for both diurnal and yearly effects of temperature. That is, he also uses the term for different optimum temperatures at different growth periods.

Night temperature has been found to have a considerably larger effect on sugar beets than day temperature (Ulrich, 1957). Parker and Borthwick (1940) concluded that soybean growth is not enhanced by night temperatures cooler than day temperatures. There appears to be no evidence in the literature that the peanut exhibits thermoperiodicity.

In Fortanier's 1957 work with peanuts, he found that low night temperature did not always give better experimental results. He felt night temperature effects were independent of day temperature. With respect to flowers and pods in peanuts, Fortanier (1957) disagreed with Went's (1953) conclusion that flower and fruit formation of plants are not connected with a certain heat summation. Fortanier found no dependency of the peanut on the distribution of temperature over night and day as did Went. Similar heat summation plants were found to act the same. The only time decisive differences were found was when the differential between day and night temperatures was more than 10 C. Fortanier found unfavorable night temperatures can be counteracted in part by high day temperatures with the reverse also being true. Therefore, Fortanier concluded that peanuts do not exhibit thermoperiodicity. He states that day versus night

temperature need not differ a certain number of degrees or that night
temperature be lower than the day to obtain optimum growth. Neverthe-
less, he says that temperature is important from germination to harvest.

Other authors (Bolhuis and De Groot, 1959; Wood, 1968) succinctly
state that the peanut shows no indications of a thermoperiodic effect.
Contrary to the above authors, though, Niclaes and Demol (1958) believe
that the peanut does show thermoperiodicity. Ulrich (1957), though
not calling it thermoperiodicity, found the average effects of different
day temperatures to not be as pronounced as the effects of night
temperatures. His data were confounded by the fact that the night period
was double that of the day.

Due to the increased ease of data compilation and the stated
lack of thermoperiodicity of peanuts by many authors, some authors
have been satisfied using constant temperatures in their research.
Spiertz (1974), in his work with the wheat plant, used a temperature
mean as night temperature treatments were in effect for twice the
length of time as day temperatures. Bolhuis and De Groot (1959)
used constant temperatures in finding that temperature greatly influences
the number of fruits formed. De Beer (1963) limited his research
to constant temperatures since he felt that there was increasing
evidence (up to 1963) that the peanut exhibits no thermoperiodicity.
He stated, though, that some differences between cultivars of the
same species may exist but would probably only be quantitative and
not qualitative. In work with soybeans, Thomas and Raper (1978)
evaluated data using constant temperatures though the experiment
used varying night and day temperature combinations. They state

that this was done for ease of data evaluation due to high day and
night temperature interactions.

Plant Development

The effect of temperature on growth and development is complex
and interactive between growth and development. Nevertheless, growth
and development should be differentiated according to Wang (1960)
and Van Dobben (1962). As an example, Wang states that flowering
is a developmental process while plant height is the result of growth
processes; therefore, the following temperature discussion is roughly
separated into developmental stages while growth stages will be dis-
cussed later.

Germination

There also is disagreement on the effect of thermoperiodicity
on separate growth and development periods of the peanut. Fortanier
(1957) concluded that development is determined by mean daily tempera-
tures as long as the range is not in excess of 20 C. Mroginski and
Krapovickas (1971) observed that plants grown from seeds treated
with alternating temperatures in a humid environment showed more
vigorous growth than did control plants. They found the processes
that produced this vigor to be nonreversible. The nature of the
processes was unknown to the authors. Montenez (1957), conversely,
found a constant temperature to be better than different day and
night temperatures for germination.

Most authors roughly agree as to the optimum temperature for
germination. A ten-day average temperature at 10 cm depth should

be 18.5 C or above for satisfactory seedling emergence according
to Mixon et al. (1969). De Beer (1963), studying temperatures between
24 and 33 C, found no striking differences in final germination percentage
up to 30 C. Germination was fastest, though, at 27 C and radical
growth greatest at 30 C. A temperature of 33 C gave poorer results
especially with respect to germination percentage. While the radical
growth was favored at higher temperatures, he states the rate of
growth was the same and that the difference in treatments was caused
by the advantage of earlier germination. While 33 C reduced germination,
further development was better. In general, De Beer (1963) says
that germination is not seriously influenced by temperature as long
as the temperature is not greater than 33 C or less than 24 C. From
his work, De Beer concluded that temperature has more influence on
further development than germination. The lower the temperature,
the longer it took for the cotyledons to appear above the soil surface
(De Beer, 1963). Bolhuis and De Groot (1959) also found the same
delay. The largest delay occurred at 21 C while 18 C had germination
but no further development.

De Beer's work (1963) coincides with Fortanier's study in 1957.
Fortanier states that germination is affected by the age of the seed,
the temperature, and the humidity. A rapid germination can accelerate
the flowering period by a few days. He found the primary root develop-
ment was most rapid at 29 C. Best results were obtained in Fortanier's
work with a soil temperature of 27 - 29 C. He felt a higher temperature
gave a more rapid water uptake by the germinating seeds. As a general
rule, a temperature of ±30 C is best. And, it appears that a high

temperature immediately after planting is more important than later
during germination (Fortanier, 1957).

Little difference in germination was found between 27 - 33 C by
Bolhuis and De Groot (1959). Provided the moisture regime is optimum,
they state that the rate of germination within a given range increases
as temperature increases. Within the range of 27 - 30 C, though, there
is little difference in germination. Toole et al. (1964) found that
optimum germination temperatures covered the range of 22.5 to 30.0 C with
no significant differences in this range for stack-cured peanuts. They
found 25 C to be most favorable for seeds with seed coats removed. Only
one-third of seeds tested germinated at 18 C and none germinated at 13 C
in a study by Mills (1964). He found the greatest response between 24
and 27 C while the greatest root extension occurred at 32 C. But, the
growth of the radical at the end of the test period was decreasing rapidly
in the case of the 32 C seedlings.

Montenez (1957) and Catherinet (1959) found optimum temperatures
somewhat higher than other authors. Montenez's data showed 33 C to
be optimum while Catherinet's data showed the best zone to be 24 - 35 C
with an optimum at 32 C.

Branch in 1974 used prechill treatments of 7 C for 0, 5, or 10
days on seeds prior to germination at normal temperatures. The treat-
ment with no prechill had the highest number of normal seedlings while
the highest number of abnormal seedlings was found at 5 days of prechill.
The level of abnormal seedlings was the same at 10 days of prechill as
it was in the no prechill treatment. Branch's experiment was performed
to test new methods for determining field germination of seed and seed
tolerance to cold temperatures.

General Vegetative Development

As discussed earlier, there is often poor distinction made between growth and development. Many authors use the term development in describing the total amount of growth (i.e.,increase in dry weight) of a plant. Others use development to describe the total state that a plant manifests -- growth, organ differentiation, and the product of the two processes. Only the latter qualifies correctly into the category of development.

Harris and Bledsoe (1951), in work in Florida, found results similar to those obtained by other researchers of growth and development. They found a high day temperature was required for normal peanut development while cool temperatures caused chlorosis and poor development. In Rhodesia, Williams (1975) states that higher temperatures associated with lower altitudes increased the amount of growth and accelerated development. He felt this result was as expected for increasing temperatures below the optimum for peanuts. The effect of temperature on the rate of development could especially be seen in the timing of reproductive developments such as pod, shell and seed growth. As an example he states that one slightly cooler location that matured at approximately the same time as another site produced 50% mature pods compared to 70% at the warmer site. The warmer site produced more mature pods in a shorter time.

Plants grown at 26/30 C (day/night) showed greater development than other treatments in work by Jacobs (1951). Several temperatures were studied by Bolhuis and De Groot (1959). They found germination but no further growth at 18 C. The best development was between 30 and 33 C depending upon variety. De Beer (1963) found that when

plants grown at 24 C were placed at a temperature of 33 C, their growth reacted the same as plants grown at 33 C since germination. If growth stopped at 24 C it could be restimulated by the 33 C temperature. The change to the higher temperature had no effect on the future reproductive phase. He concluded that vegetative development was limited at 24 C. When plants were transferred to 24 C from 33 C growth arrested shortly after the change. De Beer believed that the latter was due to the 33 C plants not yet surpassing the vegetative developmental stage that they would have achieved if grown at 24 C continuously. The results of his experiments indicated to De Beer that the duration of vegetative growth is more dependent on physiological development than age of the plant. When transferred to the cooler temperature, the 33 C plants started and completed rapidly their reproductive growth since fruit development was inhibited at 33 C.

Leaf Development

Leaf development is of extreme importance. Light and temperature control the plant chiefly through the leaves (Fortanier, 1957). Leaf formation controls the assimilation area and therefore the production capacity of the plant, Fortanier states.

Maeda (1968), while studying mainstem development, found that planting peanuts earlier (cooler temperatures) slightly affected leaf emergence and development of epicotyl primordia already differentiated in the dormant embryo and inhibited the new differentiation in the epicotyl apex. The latter caused a "lag phase" in stem growth not seen in later plantings. The number of leaves produced per day

had a high correlation to temperature up to 20 days of growth but the correlation was lower over the life of the plant. Fortanier's (1957) work showed leaf formation to be the most normal at about 30 C. At a day temperature of 15 C leaves were chlorophyll deficient. Ono et al. (1974a) discovered that the leaf emergence rate on the mainstem was promoted as temperature increased. But, regardless of temperature, a change in the rate of emergence was found at the time of the fourth leaf emergence (Ono et al., 1974a).

Peg Development

According to Fortanier (1957), the period between fertilization and peg appearance can be quite variable. The shortest period he found was five days and the time to appearance of the last peg after the cessation of flowering was 41 days. Temperature probably has an effect on this time as Stern (1958) observed a marked drop in temperature at the end of the season inhibited peg development and prevented further pod development. Carlson et al. (1975), in a study on macromutants, found that they generally produced more flowers and pegs at 30 C day and 26 C night temperatures than at higher or lower temperatures. De Beer (1957) states that a temperature of 33 C either prevented flower fertilization or retarded embryo develop-ment in his study. More pegs were produced at 28 and 24 C than at 33 C in De Beer's work. Jacobs (1951) found a somewhat cooler night temperature caused a more rapid formation of pegs and a larger total number when grown at a day temperature of 26 C.

Pod Development

A lack of pods on a plant can be attributed to two things according to De Beer (1963). The first concerns factors inherent in the plant such as genetic inhibition, and the second concerns factors external to the plant such as environmental factors. Gupton (1968) has stated that the micro-environment beneath the soil surface and the micro-climate above the soil surface may have a significant influence on the maturation process.

There is evidence to show that low temperatures can retard fruit development (Jacobs, 1951; Shear and Miller, 1955). Ono and Ozaki (1974) studied the effect of air temperature after peg penetration on pod development. They found the effect was most remarkable at the 21 to 30 day post peg penetration stage. Pod development was suppressed according to retardation of the time of peg penetration. This retardation apparently caused the pod to develop under cooler air temperatures. Ono and Ozaki (1974) found a high positive correlation between air temperature and mean pod weight. Since the depth that pods normally develop is approximately 5 to 10 cm, only a minimum delay would occur before the soil at that depth would reflect cooler temperatures.

Stern (1968) has also noticed that low soil temperatures occurring later in the growing season may lead to lower yields. His data, though are confounded by the fact that moisture was the most limiting factor. Low pod and seed weights were also found. Stern felt that the minimum temperature is of most importance. A temperature of 30 C was found to be the best for "normal" pod development by Fortanier (1957). Shear and Miller, in their 1955 work, found a close correlation between decreasing temperature and decreasing growth rate (rate

of development) of later-formed fruit. While they believed temperature
to be an important factor in the growth rate of fruit, other factors
such as decreasing daylength, declination of the sun, and the presence
of older fruit may also have a contributory effect on reduced growth
rate of later-formed fruit. In soybeans, Thomas and Raper (1978)
found the coolest of their 25 temperature treatments did not form
pods though floral initiation had occurred.

High temperatures also appear to affect pod development. De
Beer (1963) states that some ovaries may remain dormant though fertili-
zation has taken place. At 33 C he found most to remain dormant.
His finding of ovary dormancy concurs with findings of Smith (1954).
Ono et al. (1974b) reported that another researcher (Takahashi) concluded
that higher soil temperatures in the range of 35 C during the summer
caused poor pod development. The work of Ono et al. (1974b) supports
the idea that higher temperatures give poorer pod development. They
state that pod development is very subject to changes in soil tempera-
ture.   These changes are usually drastic due to the proximity of
the podding zone to the soil surface. Their data showed that most
rapid development occurred in a soil temperature of 31 C. A low
temperature of 15.5 C gave the lowest developmental rate. Within
the range of 15 to 33 C, Ono et al. (1974b) report that their findings
concur with other authors' findings that the higher the temperature,
the greater the growth and development.

Ono et al. (1974b) state that the most critical period during
which temperature affects pod development is the first 30 days and
especially between 20 and 30 days after peg penetration into the

soil. Dr. J. H. Williams (personal communication; Crop Breeding Institute, Salisbury, Rhodesia) found peak sensitivity to occur later in development than that suggested by other authors. He felt this might be due to conditions at the experimental site.

Though not strictly relating his results to temperature variation, Davis (1968) reported that fruit produced from various planting dates generally reached the same stage of maturity on the same date. This finding might be explained by Gupton's (1968) conclusion that the effect of temperature on peanut seed maturity may be related to its effect upon photosynthesis and translocation since both affect dry matter accumulation in the seed. Dr. J. H. Williams (personal communication; Crop Breeding Institute, Salisbury, Rhodesia) believes that lower sensitivity to temperature during pod setting phases compared to other plant phases probably is the result of the peanut's ability to vary the development of established fruits in relation to the photosynthate supply.

Most pods are formed at the cotyledonary branches with a large percent also formed at the third and fourth stems. Temperature was found to have no effect upon the distribution of pods over the plant (Fortanier, 1957).

Schenk (1961) discusses in great depth peg elongation, initiation of fruit enlargement, weekly development of the fruit, developmental period length, and criteria for estimating maturity. While his work does not discuss temperature in relation to these areas, his work presents a sound basis for comparing various temperature effects on the peanut plant.

Flower Formation and Development

There is a very large amount of data in the literature concerning flowering. This fecundity is probably due to the relative ease of taking flower counts and the belief of many authors that flowering controls pod formation rather than flowering being correlated with and possibly controlled by pod formation. Flowering, in the peanut, is usually described as having a frequency curve similar to a normal frequency distribution with slow increase, fast increase, peak, and decline states (Bolhuis, 1958b; Bouffil, 1947; Goldin and Har-tzook, 1966; Shibuya, 1935; Smith, 1954). Flowering usually extends over a two or three month period but this can be modified by many external environmental as well as internal plant factors. Smith (1954) found flowering to continue until the plants were killed by frost while McCloud (1974) found flowering to cease before the end of the growing season. Varietal differences probably cause many disparities in flowering data.

While the study of flowering can present an insight into what is happening under the soil surface--Fortanier (1957) states that abundant flowering can forecast a good harvest if other factors such as plant nutrition are normal--actual flower numbers are probably not of as much importance as one would suspect from the literature. Peanut plants always produce more flowers than pegs or pods (Bolhuis, 1958; Duncan et al., 1978; Fortanier, 1957; Goldin and Har-tzook, 1966; Joshi and Gajipara, 1971; McCloud, 1974; Smith, 1954). Williams et al. (1976) believe that the number of flowers that finally develop into pegs and pods is controlled by the photosynthate supply during

the pod setting stage. The flowering efficiency of peanuts in pro-
ducing mature pods is normally between 10 and 20 percent (Cahaner
and Ashri, 1974; Goldin and Har-tzook, 1966; Smith, 1954). This effi-
ciency depends, to a large extent, upon genotypes (Joshi and Gajipara,
1971). Nevertheless, under abnormal conditions it could be possible for
flowering to become the limiting factor in pod production. The following
review is only a short treatise of the available literature.

Flower initiation. Flower initiation can be regarded as the transi-
tion from the vegetative to reproductive phase (De Beer, 1963) The effect
of temperature on flowering is reflected mainly in flower development
(Bolhuis and De Groot, 1959; Shear and Miller, 1959; Smith, 1954).
Jacobs (1951) and Fortanier (1957) have found that the appearance
of the first flower is influenced greatly by temperature. Bolhuis
and De Groot (1959) state that flowering usually occurs 30 days after
planting in the tropics but retardation of flowering occurs at lower
temperatures. Basically, they found that average temperatures below
23 C increased the number of days between germination and first flowering.
It is possible, according to Bolhuis and De Groot (1959), that tempera-
ture also has an indirect effect upon flowering by its effect on
the retarded vegetative growth at unfavorable temperatures.

Ono et al. (1974a) found the days to first flowering to decrease
as air temperature is increased. They also assumed that the flower
buds are formed at an earlier stage than actual flowering thus showing
that temperature (air) had a direct effect upon flowering in their
study. Flower bud initiation exists even in the earliest phases of
plant development according to Rossem and bolhuis (1954). Fortanier

(1957) states that bud formation is not directly affected by temperature but is more dependent upon leaf axil formation. Went (1944) also found that, in tomato, temperature has little effect on flower bud formation but more effect on future development. Fortanier (1957) says that temperature has most of its effect on the elongation and opening of the flower bud.

A warm day and night temperature was found by Jacobs (1951) and Cheliadinova (1944) to produce the earliest flowers. Even after flowering has been initiated, a sudden decrease in temperature may almost stop flowering according to Bouffil (1947) and Fortanier (1957). In comparison, Thomas and Raper (1978), in work with soybeans, state that the time of floral initiation was the least subject to change by day or night temperature of all the vegetative and reproductive factors studied. They did find, though, that warm night temperatures shortened the time from first inductive photoperiod exposure to anthesis.

Contrary to the findings of Bolhuis and De Groot (1959), Davis (1968), in work with a Spanish peanut variety, found the number of days to flowering to decrease as the planting date was delayed in his field experiments. The earlier dates had more days [sic] of temperatures of 80 F or above. Maeda (1968) has found the number of days to bloom to vary markedly with year and sowing time. Temperatures during his plants' preflowering period affected the earliness of flowering. In temperature combinations with similar averages, Fortanier (1957) found the ones to flower first were those with the smallest day-night temperature difference. If the difference was greater than 20 C, there was no flowering. He found flowering to be earliest at an average temperature between 25 and 35 C.

Fortanier (1957) concluded that the division of temperatures between night and day is less important than the average temperature as long as the difference is less than 10 C. But, he states that flowering can be accelerated by a high night temperature. When night temperatures are low, the period to first flower is determined especially by day temperature.

The effect of temperature on flowering is at least partially related to the morphological change of a vegetative branch to a flowering system Fortanier (1957) says that the flowering system of the peanut is not exclusively generative. Nevertheless, the lack of a strictly generative system is of no particular importance to peanut growth. Gregory et al. (1951) state that what is customarily a reduced and simplified branching system sometimes may become very involved by maturity. Whether a flower system or stem develops in a leaf pit is largely dependent upon temperature (Fortanier, 1957). A single stem can have several changes between reproductive and vegetative states.

According to Fortanier (1957), there are three stages of the flower bud. They are: 1. formation; 2. out-growth; 3. opening. Stage #1 cannot be controlled. Stage #2 is delayed by temperatures lower than 20 C while high temperatures increase out-growth. Stage #3 is the easiest to control by temperature and other means. The optimal average temperature is 30 C. Plant branching is increased at 35 - 40 C but at the expense of bud out-growth.

Post initiation effects. De Beer (1963) found that plants could be restimulated to flowering (after they had stopped) when transferred

from 24 to 33 C. Fortanier's (1957) work showed temperature had
little effect on the time of day that flowers open. But, the time
of day at which they close is strongly temperature dependent. He
also found the length of the calyx tube is influenced by temperature.

Fertilization. There is wide disagreement in the literature
as to the exact effect temperature has on flower fertilization. Under
unspecified conditions, Smith (1954) found 93% of flowers to be fertil-
ized while only 63% of those developed into pegs. Bolhuis (1958a)
found some plants to be 80% efficient in producing fruit while the
overall average was 30%. According to Fortanier (1957), this effi-
ciency is greatly influenced by the temperature distribution over
night and day. A different optimum for fruit development than for
fertilization was indicated by Fortanier's work. He found a high
night temperature to increase peg number but not pod production.
A cool night was found to produce more pods but fewer pegs. In general,
Fortanier (1957) found that as the night temperature decreased the
day temperature needed to be higher. Cheliadinova (1944) found the
percent of fertilized flowers was more affected by temperature than
daylength. The percentage increased with temperature. Fortanier
(1957) also found the latter.

De Beer (1963) states that flower efficiency decreases markedly
at 33 C because of pollen inviability while temperatures between
24 and 28 C showed little difference in fertilization. Williams
(1975) questions De Beer's findings of pollen inviability since the
ovules were not studied microscopically and Smith (1954) found most
ovules to be fertilized under normal conditions though the efficiency

of peg and pod production was still low. Bolhuis and De Groot (1959) also found 33 C to be detrimental to fertilization while 28 C appears best. De Beer (1963) found the percent fertilization to be lower when plants were transferred from 24 to 33 C than when they were transferred from 33 to 24 C. Chang (1974) showed the ratio of fertilized flowers to decrease as temperature decreased. His data showed 15 to 20 C to be too low.

Flower distribution. Fortanier (1957) states that the location of flowers on each stem is temperature dependent although the distribution over all the stems is not. The largest number was found to form in the leaf axils of the cotyledonary stems. Fortanier's warmest treatments had flowers only in the lower leaf axils. Pod distribution was found to correspond well with the flower distribution.

Flower number. Temperature has both a direct and an indirect effect on the number of flowers produced. As an indirect effect, the inhibition of fruit formation is a stimulus for an increase in the intensity of flowering, an increase in the length of the flowering period, and therefore an increase in flower number according to Bolhuis (1955). In general, Fortanier (1957) found that the shortest flowering plants form the smallest number of flowers but the largest number of fruit.

The direct effect was found to be marked for both day and night temperatures by Wood (1968). This effect was also found to extend beyond the treatment period. He found lower temperatures to favor a higher number with no evidence of specific day or night temperature effects. The direct effect appeared to Wood (1968) to be similar in magnitude to the net assimilation rate of the plants studied.

He did not find any compensatory flower growth (after the temperature treatments ended) as might be suggested by Smith's (1954) and Bolhuis' (1958b, 1959) flower removal studies.

In contrast to Wood's (1968) work, Fortanier (1957) states that day and night temperature distribution very much affects the total number as well as lateness or earliness of flowering. He found that early flowering consistently gave fewer flowers while late flowering produced more. Of two experiments he performed, flower removal in one confounded flower numbers. The flower removal experiment showed different temperature effects than the other experiment. Therefore, it is impossible to compare the two. The nonremoval study showed that at 23 and 32 C night temperatures, the coolest day temperature studied (20 C) gave the highest numbers. The removal study showed that a day temperature of 25 C gave the greatest numbers at both 20 and 35 C night temperature. A temperature combination of 40/35 (day/night) produced only a few flowers and Fortanier's 15/20 treatment also produced only a few flowers. Fortanier states that the latter treatment is close to the critical level for vegetative growth. Jacobs (1951) found a temperature combination of 18/16 to produce no flowers.

Suzuki (1966) found that higher air and soil temperatures combined with a low soil temperature variation gave the most flowers. In Senegal, Gautreau (1973) found plants grown under hot (4 C maximum, 23 minimum), moist, greenhouse conditions to produce the most flowers while those plants at dryer and slightly cooler (40 C maximum, 20 C minimum) greenhouse conditions or in humid, cooler (33 C maximum, 23 C minimum) growth chamber conditions produced fewer flowers.

An earlier sowing is said by Joshi and Gajipara (1971) to lead to more flowers. The earlier sowings would have cooler temperatures than the later sowings. Nicholaides et al. (1959), on the other hand, state that flower production generally increases as temperature increases. Contrary to all other literature, Chang (1974) found no significant temperature effects on flower number though the number fertilized was affected.

Flower number vs. pod number. Much of the effect that temperature has on flowering is caused indirectly by temperature effects on pod numbers. Fortanier (1957) found that plants with fewer fruits produced more flowers and pegs. According to Fortanier, the relation between fruiting and flowering is caused by the control of flowering by the presence of fruits. The peg has no control. More fruits are needed, he states, to end flowering in a large and vigorously growing plant than in a small one. Fortanier could not explain this control. Stokes and Hull (1930) found that both flowering and continued development of fruit primordia are controlled by the presence of fruits. New pegs would form when old fruits were removed in their study. The data of Stokes and Hull agree with Smith (1954) who found that fruit primordia can remain dormant by the influence of developing fruits.

Davis (1968), in several experiments, showed that most mature fruits were produced from pegs formed during early flowering while few were produced from pegs formed in the later days. The latter agrees with Fortanier's (1957) idea of fruit control. Fortanier found that a rapid fruit formation would control flowering rapidly and limit the final flower number. Flowering does not start again, according to Fortanier, because

fruits are ripening over a long period of time. Once all are ripe,
flowering can begin again. Contrary to all other literature found, Wood
(1968) came to the conclusion that developing fruits have no direct
effect in suppressing flowering. He based this conclusion on his
finding of no apparent relation of flowering to fruit weight.

Flowering periodicity. Throughout the literature, there is constant
mention of the peanut exhibiting flowering periodicity. There appears
to be a general concensus that environmental factors can cause flowering
periodicity. The periodicity normally exhibits itself two to four
days after a change in environmental conditions (Bolhuis, 1958a;
Bouffil, 1947; Nicholaides et al., 1969; Shibuya, 1935; Smith, 1954;
Uman, 1933). There also appears, though, to be a periodicity inherent
in the peanut regardless of outside conditions. Fortanier (1975)
found what he called a "double periodicity." His "big periodicity"
is that caused by factors such as weather and is superimposed upon
a "small periodicity" which is under the control of the plant.

Davis (1968) found alternating flowering frequencies but did
not relate these to weather or internal factors. Bouffil (1947)
and Smith (1954) also found periodicity but did not find a "double
periodicity" as did Fortanier (1957). Smith states: "The constancy
of flowering periodicity despite the variety of daylengths and climatic
conditions under which the observations have been made, clearly suggests
that cyclic flowering is inherent in the developmental processes of the
peanut plant and is not directly controlled by variation in factors of
the external environment." (Smith, 1954, pp. 612-614).

Bouffil (1947) also did not relate the periodicity he found to environmental conditions. He could not find a relation to climatic factors as he found periodicity to occur in different geographical areas. Bouffil did find, though, that a sudden decrease in temperature may almost stop flowering two or three days later. Williams (1975) indicates that Bolhuis' (1958a) conclusion that flowering variation is only slightly related to climate is suspect since his data appear confounded by plant density variation and a difference in the fruiting percentage of various treatments.

Fortanier (1957) showed that a periodic drought or unfavorable high and low temperatures caused a periodic flowering three days later. A flush of flowers would occur three days after watering or return of more favorable temperatures. He also found that the daily period at which flowers open is strongly light and spectral sensitive. The effect is seen three days later. Both Niclaes and Demol (1958) and Wood (1968) found an effect of temperature on flowering with a lag time of three days. Nicholaides et al. (1969) found the "double periodicity" of Fortanier (1957). They found individual plant fluctuation within temperature controlled flowering cycles. The temperature controlled fluctuations were positively correlated to the highest, lowest, and mean temperatures two to three days previously. The average temperature was the best correlated.

Conclusions. The literature shows that flowering is affected by temperature but little agreement is present. An example of this disagreement is De Beer's (1963) and Bolhuis and De Groot's (1959) work. Both works used the same varieties with similar treatments and in some cases showed responses substantially different although the experiments were conducted in the same growth chambers.

Fortanier (1957) has found that with different environmental conditions no relation exists the same in all cases. He says: "Undoubtably a relationship exists between the number of flowers and fruits formed, although that is not simple to describe on a percentage basis" (Fortanier, 1957, p. 100). In experiments on the influence of external conditions on flowering, the influence of fruits must carefully be taken into account (Fortanier, 1957). Likewise, fruit and flower observations must occur together to come to a correct conclusion on how environmental factors affect fruit formation, according to Fortanier (1957).

The main importance of studying the flowering of the peanut plant is, according to Fortanier (1957), to find whether the plant flowers under certain conditions and what the progress of that flowering is. Then, if the flowering does not meet expectations, the causes can be investigated. The percentage of flowers from which pegs or pods develop is more important than the absolute percentage of fertilization (Fortanier, 1957). However, recent research at the University of Florida indicates that, under normal environmental conditions, the number of flowers produced is of little importance (McGraw, 1977; Drs. D. E. McCloud and W. G. Duncan, personal communication). Pods were found to increase at a linear rate regardless of the flowering curves (McGraw, 1977; McGraw, 1979). In other words, flowers and fruits are unrelated except for the effect of pods on flowering cessation at full pod load. In practical terms, Fortanier (1957) states that control of flowering is of small importance.

De Beer (1963) concluded that the temperature during the vegetative phase has little or no influence on the later development of flowering. Flowering is mainly dependent on the temperature during generative

development. These conclusions are in contradiction to other authors. Fortanier (1957) states that certain treatments control not only flowering but also stem elongation, branching, leaf formation and seed formation. All the latter influence flowering. He succinctly states that flowering tends to be dependent upon the preceding growth processes. Vegetative and generative processes continue from germination side by side (Fortanier, 1957). Goldin and Har-tzook (1966) found that vegetative growth and flowering cannot be antagonistic.

Wood (1968) and Fortanier (1957) both concluded that the production capacity of the peanut is not determined by the number of flowers produced per se but by the assimilation rate of the plant. Wood (1968) states that flower production is controlled by the availability of photosynthate while Fortanier says that the plant can bring into complete development no more than a certain maximum number of fruit. Conditions that improve flowering are, in general, also favorable for fruit formation (Fortanier, 1957).

<u>Node Number</u>

There is a scarcity of information concerning the effect of temperature on node number. Williams (1975) found little direct information in his literature search on node number in peanuts. He assumed that node number is closely related to the number of leaves. Therefore, he states that researchers show that node number increases with temperature to about 30 C.

Gautreau (1973) studied internode length but not node number. Thomas and Raper (1978) found mainstem node number in soybeans was only moderately affected by temperature variations.

Growth Period Length

The final size of a plant is determined by mutually independent effects of temperature on growth rate and rate of development (Van Dobben, 1962). As an example, a temperature of 25 C shortens the development period of temperate zone crops but does not speed growth. Smaller plants result (Van Dobben, 1962). Ulrich (1957) states that stages within the beet plant are not self-regulatory but are induced by specific factors of its environment. In wheat, Spiertz (1974) found that the acceleration of leaf senescence and ripening of the kernels at higher temperatures is more important for final yield than the increase in growth rate caused by the higher temperature. He felt that more assimilates are used for grain growth at the expense of the internodes and roots at the higher temperature. A shorter growth period results.

While it is apparent from the literature that temperature affects the lengths of various phases of plant growth, it also appears that these phases can be affected to different degrees. The degree of influence of air temperature upon the peanut plant's mainstem growth (cm/day) and development (leaves/day) differs with growth stages, according to Maeda (1973). Dr. J. H. Williams (personal communication; Crop Breeding Institute, Salisbury, Rhodesia) states that the existence of phases of growth that are more sensitive to the environment than others has been known for a long time. His research data indicate that periods exist, in the peanut plant, of above average sensitivity to the environment. This sensitivity pattern was the same for almost all varieties tested. The reasons for the pattern are unknown (Dr. J. H. Williams; personal communication; Crop Breeding Institute,

Salisbury, Rhodesia). De Beer (1963) states that a good temperature for vegetative development may not be so for reproductive development.

While various plant developmental phases show varied temperature sensitivity, they are also interdependent upon each other. Fortanier (1957) found, in a temperature experiment, that conditions in which peanut plants were grown during the first two and one-half months had a large influence on further development when the plants were subsequently grown in similar conditions.

The life cycle of the peanut plant can be divided into four developmental phases. Fortanier (1957) divided the life cycle into four phases of 25 to 30 days each. They are: first phase--growth; second phase--flowering; third phase--seed formation; fourth phase-- ripening. He states that it is not possible to distinguish a sep- arate period of fruit formation. For the purposes of the following discussion, the four phases will be: 1. vegetative; 2. flowering; 3. pegging; 4. filling.

Total growth period. Williams (1975) found higher temperatures to increase the rate of phenological development. Nevertheless, the coolest temperatures studied did not lengthen the period of the plant's life cycle over that of intermediate temperatures. He found less pods to reach maturity at the cooler temperatures. It appears from Williams' data that growth factors modified the temperature effect on developmental rates. According to Davis (1968), the optimum harvest dates for Spanish peanuts were 130 - 137 days after planting for early planting dates and 116 - 123 days for later planting dates.

Vegetative period. This period of development is the period of time from germination to the first flowering of the plant. The variation of this time has been discussed relative to flowering in the previous section "Flower Initiation." From the research of Bolhuis and De Groot (1959), Carlson (1972), and Wynne and Emery (1974), Cox and Martin (1974) concluded that the effect of temperature on this growth period differs with variety and that the effect of temperature on the rate of development in this period may be curvilinear.

Flowering period. Most of the literature on the flowering period of development has been reviewed under the previous section "Flower Number vs. Pod Number."

Moore (1937) states that, in the case of the peanut, vegetative growth and reproduction are not opposing tendencies but are compliments in the normal course of development. De Beer (1963) agrees that flowering and vegetative growth are not opposing tendencies but stresses that fertility of the flowers and fructification in relation to vegetative growth are another matter. He states that fruit growth and vegetative growth are opposing tendencies. But, De Beer feels that it is not merely the number of mature fruits but the number in relation to vegetative mass that counteracts vegetative development. As long as the plant can be stimulated to vegetative growth, De Beer asserts, it can also be stimulated to further flowering.

Williams (1975) found, in his research, that with warmer temperatures the reproductive phase started earlier. The duration, though, was not closely related to mean temperature. He states that his finding is in direct contrast to other crops in Rhodesia where authors

(Crackett and Wall, 1971; Wilson et al., 1973) have found increasing temperatures to reduce the duration of reproductive growth and vegetative growth.

Pegging period. Literature is scarce on the actual length of time that pegging takes place. Some mention of this period is also included in the section "Flower Number vs. Pod Number." Duncan et al. (1978), in work modeling peanut growth, used a working hypothesis that the duration of fruit initiation (pegging) is affected by planting rate and climatic and edaphic factors. He did not have experimental evidence to support this assertion.

Filling period. The filling period length, by itself, has not been discussed in any more detail in the literature than the other periods. Normally, Fortanier (1957) states, it takes 30 to 40 days after peg penetration for the fruit to reach maturity. Williams (1975) found that his medium and high temperature treatments did not vary much in length though a higher growth rate (due to more pegs) occurred at the medium temperature. The coolest temperature filled fruit for a shorter time due to the temperature's effect on other plant growth factors. There was a greater duration, though, of a high growth rate at the medium temperature. Williams (1975) states that the lack of a distinct temperature effect on the duration of filling period is in contrast to the temperature effect on other crops grown in Rhodesia (Crackett and Wall, 1971; Wilson et al., 1973).

Williams' (1975) findings also contrast with data from Spiertz (1974), who, working with wheat, found that within a temperature

range of 15 - 25 C the post-floral development period was shortened
considerably. Ono et al. (1974a) list 31 - 33 C as optimal soil
temperatures for pod development while 15 - 17 C is minimum and 37 - 39
is maximum. They state this development is a function of pod size
and weight.

Plant Growth

The increase in weight of separately grown plants is exponential,
according to Van Dobben (1962). In the generative phase, though,
growth rate is slowed considerably due to the formation of nonas-
similating tissue. Within the range of his investigations, Van Dobben
found subtropical and tropical plant growth rates to increase without
reaching an optimum value. There is a general tendency, he observed,
for temperate zone crops to reach greater total dry weight in cooler
climates while tropical plants show a faster growth rate without
a commensurate increase in the speed of development as the temperature
increases.

Williams (1975) concluded that the influence of temperature
on the reproductive potential of groundnuts appears to operate through
temperature's effects on crop growth rate. This conclusion was based
on peak growth rate and peg numbers being well correlated. In his
coolest treatment, the low temperatures (mean 18 C) limited the growth
of the vegetative components. The reduced vegetative component growth
reduced the reproductive potential by limiting peg production. The
reduced crop growth rate was not completely caused by a reduction
in photosynthetic capacity of the leaves since when the reproductive
sink was generated, there was an increase in the crop growth rate

(Williams, 1975). Williams (1975) found that as the temperature became warmer, the crop growth rate increased. The increase is as expected, he says, for temperatures below the optimum for peanut growth. Shear and Miller (1955) concluded that a close correlation exists between decreasing mean temperature and decreasing growth rate.

In his work with wheat, Spiertz (1974) found an increase in the growth rate of the grains within a temperature range of 15 - 25 C. The postfloral development, though, was shorter thus causing a lower grain yield. He states that the rate of grain growth in wheat is related to various physiological processes. The assimilate supply is determined through a series of physiological processes affected by climatic factors as shown in a model presented in his paper. The transport of this assimilate is also controlled by temperature and this affects the growth rate of the various plant organs. Van Dobben (1962) states that the distribution of dry matter (assimilate) is important for growth rate, yield level, and final product harvested. He concluded that differences in growth rates between species and varieties are mainly due to the rate at which assimilates are converted to assimilating tissue and by the green area formed per unit dry weight.

Grain growth of wheat is determined by the supply of carbohydrate and the sink capacity of the head, according to Spiertz (1974). One might conclude, he states, that the final grain yield depends on the balance between carbohydrate supply and head capacity. But

temperature, in his experiment, affected the rate at which carbohy-
drates could accumulate in the wheat head. Low temperatures and
a high light intensity gave a surplus of carbohydrates.

Growth and Development Critical Temperatures

Some mention of critical base, optimal, and maximum temperatures
has been made in previous sections of this review. Most of the effort
towards determining these values has been made by researchers inter-
ested in developing heat unit indices.

General growth. Bolhuis and De Groot (1959) found no growth
or development to occur below a constant temperature of 20 C. This
is substantially higher than that found by Mills (1964) and Emery
et al. (1969) who found a temperature of 13 C to be basal for growth.
Different varieties, though, were used and the value of 13 C was
obtained in temperature combinations and does not represent a constant
value. De Beer (1963) concluded that 24 C is too low and 33 C is
too high for normal growth of the varieties that he tested. These
are constant temperatures. Bolhuis and De Groot (1959) also found
that below 24 C growth is greatly retarded (i.e. no flowering or
fruit set). They also agree with De Beer (1963) that 33 C is unfavor-
able, producing an excess of vegetative growth at the expense of
pods. In De Beer's (1963) experiment, vegetative growth was limited
at 24 C while at 33 C fertilization of the flowers was hindered.

The above temperatures compare favorably with results of Fortanier
(1957) who found that below 20 C all growth processes stopped and
temperatures above 30 C were harmful depending upon humidity. A

day temperature of 35 C is almost maximum, Fortanier states, and is unfavorable for flowering. He also concluded that a day-night differential of less than 20 C is critical for flowering to occur. Flower buds nevertheless formed.

Cox and Martin (1974), in determining a mathematical relationship for growth from planting to flowering, found an optimum minimum mean temperature between 15 and 17 C for three varieties tested. Optimum maximum temperature varied with variety with values of 32, 33.5 and 39 C. A base minimum temperature for growth was found to be 6 C for the three varieties. The 6 C temperature is considerably below the minimum temperature found by other authors. A base maximum temperature between 20.5 and 20 C was found by Cox and Martin (1974).

Average optimum temperatures differ over a plant's life cycle and generally decrease as the plant gets older, according to Went (1953). Bolhuis and De Groot (1959) found an apparently greater tolerance, in respect to the number of pods, to a change in maximum temperatures with varieties that are adapted to growing conditions at higher latitudes.

Germination. Germination but no subsequent growth at 18 C was obtained by Bolhuis and De Groot (1959). The results of Mixon et al. (1969) agree with the 18 C minimum temperature.

Flowering. In a study by Bolhuis and De Groot (1959), only one cultivar flowered at 21 C. De Beer (1963) lists temperatures greater than 33 C and lower than 24 C as unfavorable for flowering. Fortanier (1957) found high day and night temperatures greater than 35 C to adversely affect flowering as well as the whole plant.

Total Dry Weight

Plant size and total dry weight are two of the most important characteristics of growth, according to Fortanier (1957). In an experiment by Wood (1968), relative growth rates and net assimilation rates showed significance for different temperature treatments for the period the treatments were in effect and for a subsequent period where all plants were grown at the same temperature. Even at 41 days after the temperature treatments, total plant weight still showed significance (mostly due to differences in fruit weight). Davis (1968) found that plant dry weight generally decreased as planting dates were delayed.

De Beer (1963) found that as temperature increased, there was an increase in dry weight. Ono et al. (1974a) showed that dry matter increased at a faster rate as temperature increased. In a 1973 study, Gautreau showed plants grown in a hot (41 C maximum, 23 C minimum) greenhouse with low relative humidity to have a lower crop growth rate than plants grown in cooler, more humid greenhouse (40 C maximum, 20 C minimum) and growth chamber (33 C maximum 23 C minimum) conditions. It appears that humidity and moisture relations were the cause of the lower rate in the warmer treatment. Dry weight at the time of first flowering was found by Ono et al. (1974a) to be greater at an air temperature of 30 C than at 20 or 25 C. The total dry mass accumulated increased as temperatures became warmer in a study by Williams (1975). The dry weight was greatest at the highest temperature and lowest at the lowest temperature. Williams found, though, that vigorous stem growth limited yield potential. This fact varies from Fortanier's (1957) and Bolhuis and De Groot's (1959) work that showed yield to be

related to total growth but helps to explain the findings of Brown et al. (1973) who found that reduced stem growth could increase the number of pods produced. Williams (1975) thought that the vigorous stem growth affected the ability of pegs to reach the soil surface and therefore reduced yield. De Beer (1963) found a close correlation between stem length and dry weight. Both increased with increasing temperature. A similar relationship was shown by Fortanier (1957).

Root Weight

Root weight was the most striking of Wood's (1968) dry weight data. He showed a marked response to temperature as did Gautreau (1973). Nielsen and Humphries (1966) state that the optimum root zone temperature for plant species indigenous to warm climates is greater than that for temperate zone plant species.

Stem Dry Weight

As temperature increased, during the vegetative period of growth, the growth rate and thus total dry weight of stems increased in Williams' (1975) study. During the reproductive period the stem growth rate is also influenced by such factors as pod growth (Williams, 1975). Factors other than temperature caused Williams' data to become quite variable after 14 - 17 weeks. The variability made interpretations difficult. De Beer (1963), Fortanier (1957), Khalik (1956), and Wood (1968) have also found stem weight to increase at higher temperatures for peanuts and Van Dobben (1962) has found the same for wheat. Fortanier (1957) found stem growth to be greater when night temperature was higher than the day temperature. He felt this finding was remarkable. The

unfavorable effect of a low day or night temperature is more or less compensated for by a high night or day temperature, according to Fortanier (1957).

Van Dobben (1962) states that the shoot-root ratio changes during development. In most annual plants, under optimal conditions, the root dominates during germination and the ratio is low. In the seedling stage, the shoot growth rate is greater than that of the root and the ratio increases. The ratio established at the end of the seedling stage remains almost constant during the rest of the vegetative growth period. During the transition to the generative phase, the ratio increases as the dry matter distribution pattern favors the plant tops. No substantial change in the ratio occurs within each phase. Distinct differences in the shoot-root ratio are present between temperate and subtropical crops (Van Dobben, 1962).

In his work with wheat, Van Dobben (1962) concluded that the shoot-root ratio shows a correlation to growth rate since the growth rate is established from light response and temperature effects. A vigorous growth rate by crops of subtropical origin at high temperatures allow these plants to grow larger despite a shorter growth period. Van Dobben believes that, at normal temperatures, the shoot-root ratio is probably the most important factor regulating growth rate. Differences in growth between varieties can probably be explained, Van Dobben (1962) says, by different shoot-root ratio and dry matter content.

Stem Branching

Williams (1975) states that there are three components to stem growth and development. They are: 1. node number; 2. stem extension;

3. branching. A number of authors (Bunting, 1955; Gregory et al., 1951; Hermann, 1954; Fortanier, 1957) discuss the sequential or alternate branching pattern of the Virginia, Spanish, and Valencia groups of peanut and the variations in these patterns between the groups. Bunting (1955) states that branching pattern can be influenced by external conditions. Both the flower and branching systems are very dependent upon climatic factors (Fortanier, 1957). Fortanier states that, along with other factors, the production capacity of the peanut is determined by the amount of branching. His general rule is that more branching equals more leaf-pits which equal more flowers.

Both De Beer (1963) and Fortanier (1957) state that high temperatures, especially above 30 C, increase branching. The most normal branching occurs at about 30 C, according to Fortanier (1957), and the greatest amount occurs at 35-40 C. He found that as temperature increases, so does the stem number (especially of extra side stems). His 40/35 treatment was most striking. In temperatures between 20 and 35 C day temperature the cotyledonary branches had the most side stems while at 40/35 all side stems had extra branching. In one experiment, Fortanier (1957) found that a changing temperature (thermoperiodicity) improved side stem formation over a constant temperature. The effect of a low day or night temperature was compensated for by a high night or day temperature.

In contrast to Fortanier's work, De Beer (1963) found that extra lateral side stems generally did not develop at any of the temperatures studied. Suzuki (1966) found higher air and soil temperatures combined with the least variation in soil temperatures caused plants

to have longer stems with more branches. In soybeans, Thomas and Raper (1978) found branch number to be only moderately affected by temperature.

Stem Height and Elongation

Thomas and Raper (1978) also found a large temperature effect on soybean branch length and mainstem elongation. Chang (1974), De Beer (1963), Fortanier (1957), and Jacobs (1951) found the same for peanuts. Fortanier (1957) showed the rate of stem elongation to be greatest at 30/25 C. Stem growth was found to increase linearly over a range of temperatures. De Beer (1963) found similar results. Gautreau (1973) found the mainstem to be taller in his coolest treatment (31-33 C maximum, 23 C minimum, high humidity).

Leaf Dry Weight and Development

Wood's (1968) use of a quadratic response surface to find a maximum leaf weight showed 25/25 C (day/night) to be an optimum temperature for this factor and for leaf growth rate. From the response surface results, Wood concluded that the 25/25 temperature combination was optimal for photosynthesis for the twelve day period that his treatments were in effect. Forty-one days after the treatment ended, leaf weight was one of two factors that still showed statistical significance but he could not relate this to immediate treatment effects.

In growing peanuts in various locations, Williams (1975) discovered that the leaf weight formed prior to reproductive growth was greatest at the site with the warmest temperature and lowest at the coolest

site, reflecting the increase of growth rates at warmer temperatures. The peak growth rate occurred sooner in William's hottest treatment. Leaf development was favored by high temperatures in De Beer's (1963) experiment. He found stem and leaf growth to be well correlated.

Leaf Number and Emergence

Maeda (1968) concluded that temperature during the preflowering period greatly affects the emerging speed of leaves on the mainstem. He found a nearly constant number of leaves at the first day of flowering among a large number of varieties. The latter was caused, he felt, by the effect of temperature on the speed of leaf emergence offsetting the effect of temperature on the number of days to flowering. Maeda felt that the number of leaves on the mainstem should be a useful character for studies on the artificial control or regulation of flowering. Leaf initiation is independent of day temperature but strongly dependent on night temperature, according to Wood (1968). The leaf formation during Fortanier's (1957) experiment progressed regularly with no periods with sudden changes. However, the leaf number remained fairly constant during the ripening period after a gradual increase. He found that the effect of temperature on the formation of leaves on the mainstem was approximately the same as the effect on the first four side stems. The largest number of leaves on the side stems were in the temperature combinations 35/20 C and 40/35 C. When plants were placed under more normal conditions (25/20) the 40/20 C treatment produced more leaves than.. the 35/20 treatment but the 40/35 treatment still had the largest number. The plants with the lowest number of leaves after the end of the treatment

period advanced the most under the favorable conditions after the
treatment period. Fortanier (1957) states that a day temperature
over 25 C did not have much effect on the leaf number on extra side
stems produced at those temperatures. The stems were poorly foliated
and the leaves small in area. Fortanier also found that the number
of leaves is apparently independent of the length of the stems. De
Beer (1963) found similar effect to Fortanier regarding leaf number.

Leaf Size

In Wood's (1968) research, there was an increase in growth rate
at 25/25 C due to an increase in leaf size rather than an increase
in the number of leaves formed. Fortanier (1957) showed leaf size
to be determined largely by day temperature. At two night temperatures
(20 and 35 C) the area increased as the day temperature increased
up to 30 C. At 40 C day temperature leaf size decreased, especially
in the 20 C night treatment. He also found that larger leaflets
of the apical leaves were well related to longer stems and internodes.
Conversely, it was found in De Beer's (1963) work that smaller leaves
were formed at higher temperatures although total leaf area was greater
due to a larger leaf number.

Leaf Area

The total leaf area of a plant depends upon both the number of
leaves and their size. The size of the leaf area is a major factor in
the amount of photosynthate available to the plant. The concept of leaf
area index (L.A.I.) was developed by Watson (1947) as a measure of leaf
area in plant stands. Leaf area index is defined as the unit leaf

area divided by the unit surface area that it covers. While the actual leaf area of a single plant indicates the growth potential of that plant, L.A.I. is a better indicator of the field crop's leaf area effect upon that crop's growth. In a field crop, it is only after 100% ground cover has been reached with an L.A.I. of at least one that all solar radiation is intercepted. However, the L.A.I. is normally much higher before full light interception occurs due to variable spatial orientation of the leaves. Monteith (1965) states that a crop without favorably oriented leaves would cease to show an increase in photosynthesis (at a specific radiation level) as the L.A.I. increases above a value of approximately five.

De Beer (1963) found similar results to those of Fortanier (1957) concerning the size of the tenth leaf on the mainstem. Both authors used the tenth leaf as a factor to determine the leaf area of the whole plant. No attempt was made in either study to determine which leaf is most closely related to the overall leaf area. At Williams' (1975) experimental sites in Rhodesia, the expansion of leaf area was greatest and the rate of expansion was fastest at the warmest site while the coolest site was lowest in both respects. Williams measured peak L.A.I.s of 7.0, 4.5, and 2.6 for the warm, intermediate, and cool sites, respectively. Along with the expansion of leaf area, the leaf area index also developed the more rapidly at the higher temperature. Williams (1975) states that his data are similar to that of Fortanier (1957) and De Beer (1963).

The growth chamber and field study by Gautreau (1973) showed leaf area to be greatest in his warm (41 C maximum, 23 minimum),

humid greenhouse treatment. His warm (40 C maximum, 20 C minimum),
low humidity greenhouse conditions showed the least leaf area.

General Pegging, Pod Set, and Pod Maturity

Zamski and Ziv (1976) present a flow diagram for factors affecting
pod formation, especially mechanical stimulus and darkness. The
diagram indicates whether or not pod formation will occur under various
conditions.

Wood (1968) and Bolhuis and De Groot (1959) found temperature
to have an effect on peg and pod number. Temperatures over the early
flowering phase had a marked effect on number in Wood's research
while constant temperatures over the life cycle of the plant greatly
affected pod numbers in Bolhuis and De Groot's work. Bolhuis and
De Groot (1959) found an optimum between 27 and 30 C for two varieties
and between 24 and 27 C for another variety. Wood (1968) found a
cooler day air temperature (20 C) to be best for a warm night tempera-
ture (25 C) while a warmer night temperature (30 C) was best for
30 C day temperature conditions. He also found no temperature effects
on mean seed weight. According to Ono et al. (1974b), 15 and 39 C
soil temperature both decreased podding rate considerably.

The change of peg and pod number found by the above authors is
contrary to Goldin and Har-tzook's (1966) statement that pod production
may remain more or less constant under changing conditions (57-69/plant)
since as total flower number decreases, pod set increases. They
also state that pod set may be inhibited by flowering and vegetative
growth. They emphasize that their findings are supported by the

findings of Bouffil (1947) and Bolhuis and De Groot (1959). The latter authors found that reducing flower number caused a pod set percentage increase. Goldin and Har-tzook's conclusions appear to be contrary to all other research findings.

The negative effect that certain temperatures can have on pod number is directly related to the effect of those temperatures on flower number (as discussed earlier) and peg number. While there are always more flowers than pods or pegs produced, Duncan et al. (1978) have also found pegs to enter the soil at about three times the rate that pods are produced. Goldin and Har-tzook (1966) mention that one of the most undesirable features of the peanut is its large number of immature pods that are usually lost in threshing. They postulated that immature pods may be related to late flowering causing the late pods to have only a short time to fill.

Collins (1966) observed that an increase in the mean number of intermediate maturity fruits occurred as harvest was delayed but he found the mean number of mature fruits not to be significantly different. There is very little information about the growth of individual pods at various temperatures, according to Williams (1975).

The ratio of pegs and pods to flowers is affected by temperature. Chang (1974) used a functional pod ratio in his research and found it to decrease at low temperatures. Temperatures below 20 C decreased this ratio sharply while high temperatures enhanced it. The number of flowers during a "functional flowering stage" (i.e.,bloom up to 30 days of bloom) was used to calculate his pod ratio. Wood (1968) found significance among his treatments for the number of pegs produced

and correlated them significantly (positive) with the number of flowers produced through his treatment period. Cooler temperatures produced more flowers and therefore pegs. Gautreau's (1973) peg percentage of flowers was lowest in his warm (41 C maximum, 23 C minimum), humid treatment due to a lack of moisture and was highest in his cooler (31 - 33 C maximum, 21 C minimum), humid growth chamber treatment. Williams (1975) showed the largest number of pegs to be formed at his warmest treatment while his intermediate temperature treatment produced the most pods but not pegs. He also found that as stem mass increased the proportion of successful pegs decreased.

Pod Number

The concept of partitioning of assimilates combined with other observations gives an insight into how the number of fruits per plant is established (Duncan et al., 1978). Shear and Miller (1950, 1955) found the removal of pegs did not change fruit number. The number of fruit that a plant of a given size produces appears to be relatively constant. The partitioning of assimilates can be affected by temperature as discussed earlier in observations by Van Dobben (1962) and others.

The largest pod set was found by Bolhuis and De Groot (1959) to be between 27 and 30 C. In 1966, Suzuki found higher air and soil temperatures along with little soil temperature variation gave the best fruit set. The highest peg/pod ratio obtained by Gautreau (1973) was for his two greenhouse treatments (41 C maximum, 23 C minimum, high humidity and 40 C maximum, 21 C minimum, low humidity). A lower value was found for his warm (31 - 33 C maximum, 21 C minimum), humid, growth chamber treatment due to physiological growth not stopping as soon as the other treatments.

The mean percentage of mature pods increased in Davis' (1968) research as the harvest date was delayed and as the planting date was delayed through the middle of June. The number of intermediate maturity fruit generally increased as the planting date was delayed while immature pods generally decreased as the date was delayed through the middle of June. While finding no increases in the number of mature seeds after 111 days of his experiment, Davis (1968) also found no significant increases in seeds of intermediate maturity.

Number of Seeds per Pod

The number of seeds per pod decreased as temperature became cooler under the experimental conditions of Williams (1975). He called the number of seeds per pod "kernel potential." The decrease was compensated for by differences in peg production and efficiency when considering total yield. Williams (1975) is the only reference for seed number per pod as affected by temperature found in the literature.

Single Seed and Pod Weight

Williams (1975) showed the total growth and growth rate of individual seeds to be greatest at his coolest site (18 C mean, 24 C maximum, 14 C minimum) and poorest at the warmest (24 C mean, 30 C maximum, 17 C minimum). The coolest site started its growth last. He felt that it was possible that stem growth competed with seeds for available photosynthate at the warmest site. The highest mean seed weight was also found at the coolest site. The weight decreased as temperature increased. Higher air and soil temperatures combined with little variation in soil temperature gave Suzuki (1966) heavier seed.

At 31 C soil temperature, Ono et al. (1974b) found pod size to increase linearly while his 23 and 39 C treatments gave an s-shaped curve. The weight of a single pod increased almost linearly in all treatments with the heaviest weight being found at 31 C and the lightest at 15 C. Seed at 39 C was also quite light. The weight per seed showed almost the same relationship.

A positive correlation between temperatures during the flowering stage and seed weight was found by Chang (1974). A low temperature decreased the weight of dry pods and seeds and therefore reduced yield. Contrary to Chang's findings, Wood (1968) showed no differences for mean pod weight due to temperature treatments during part of the flowering period.

Davis' (1968) temperature experiments showed both the weight and number of mature, intermediate and immature seeds to correspond closely. When one showed significance, so did the other. His data also indicate that beyond about 110 days temperature does not have an effect upon the peanut fruit weight (total or single). Fruit weights did not change appreciably after this day in any of his treatments.

Shell Growth and Shelling Percentage

The three sites that Williams (1975) used in his temperature study differed little in shell growth. But, shell growth started earlier as mean temperature increased. The intermediate temperature growth was prolonged longer. The intermediate temperature also showed the most shell growth but Williams (1975) felt this was not of major

significance. Wood (1968) found no treatment differences in his
temperature study in respect to shelling percentage. But his treatments
only lasted during part of the flowering period. Chang (1974) also
found no significance for shelling percentage due to temperature
during flowering.

Total Seed and Pod Yield

The total yield of seed and/or pods is a combination of all
the factors reviewed earlier. Van Dobben (1962) states that final
yield is determined by growth rate and the length of the growth period.
The ultimate size of a plant is determined by a mutually independent
influence of temperature on growth and development. Van Dobben found
pea plants to be smaller at higher temperatures due to a shortening
of the growth periods that was not compensated for by more vigorous
growth. In Spiertz' (1974) work with wheat, the acceleration of
leaf senescence and ripening by high temperatures was more important
than an increase in growth rate. While yield at cool temperatures
was related to kernel characteristics, the yield at high temperatures
was affected by developmental rates. Respiration of leaves increased
at higher temperatures and the growth rate of the kernels also increased.
Spiertz felt that the latter could only happen under a situation
where there is no shortage of assimilates. He believes that grain
growth and yield is determined by the supply and balance of carbo-
hydrate with sink capacity.

Final yield largely depends upon a plant's longevity. This
longevity, Van Dobben (1962) says, depends on phasic development

and this is affected by climatic developments. Temperature has a direct and an indirect affect on yield (Van Dobben, 1962). Fortanier (1957) believes that yield in the peanut is dependent upon vegetative development and on flowering progress.

The composite and interaction of all plant physiological processes upon individual seed weight, individual shell weight, seed number per shell, and shelling percentage produces the final economic yield of seeds in the peanut. The literature, citing yields obtained under various temperatures, is slight. Most authors have not attempted to compare total seed or pod yields in their various treatments.

According to Williams (1975), seed yield is not well related to mean temperature, total dry mass, crop growth rates or L.A.I. Nevertheless, Williams found that total pod yield clearly showed the effect of temperature between the time of planting and the beginning of reproductive growth. His experimental site that was intermediate in total dry mass, crop growth rates, and L.A.I. had the highest yield. This yield was achieved by a rapid early growth that started later than his warmest temperature site. Since his mean daily temperature was lower than that listed by Bolhuis and De Groot (1959) for limiting plant growth, he felt that his data were at variance with theirs.

Cheliadinova (1944) found the yield of fruit to increase considerably under conditions brought about by a higher temperature. High temperatures and moderately low rainfall were found by Shear and Miller (1950) to favor yield and quality. Seasonal variations in temperature and rainfall caused marked differences in their data.

Observations by Harris and Bledsoe (1951) indicated that an increase in temperature increases the yield of fruit. Higher air and soil temperature combined with little variation in soil temperature produced the highest yields for Suzuki (1966). In his experiment at the phytotron of the Taiwan Agricultural Research Center, Chang (1974) showed highest yields when his temperatures (applied during blooming stage) were high. Low temperatures lowered yield sharply. For vegetative/ fruit weight ratios, Gautreau (1973) found his warmest (41 C maximum, 23 minimum), humid greenhouse treatment to have the highest ratio.

Contrary to results for the peanut plant, Lambert and Linck (1958) found that the higher the temperature, the more the yield of pea plants was reduced. They concluded that this reduction was due to an increase in respiration or a reduction of nutrients needed for ovule development.

According to Ono and Ozaki (1974), the effect of air temperature is very striking between 21 and 60 days after the time of first flowering. The effect of temperature on yield in Wood's (1968) research was due to the effect on the number of developing pegs. Wood showed a high correlation of yield with net assimilation rate during the period of his treatments. The temperature effect on yield was caused by the effect of temperature on the growth rate of his plants. Growth rate determines the number of flowers which in turn determines the number of pegs and fruits. Nevertheless, Wood (1968) could not state with certainty whether his final yields were determined solely by net assimilation rates or by the level of flower production in conjunction with the net assimilation rate.

MATERIALS AND METHODS

Experimental Location

The research presented in this dissertation was conducted at
the Duke University Phytotron of the Southeastern Plant Environment
Laboratories (SEPEL). The Duke Phytotron is located on the Duke
University campus in Durham, N. C. Some measurements were made with
equipment located at the North Carolina State University Phytotron
of SEPEL. Other measurements were conducted at the University of
Florida. All measurements made outside of the Duke Phytotron were
on plant material removed from the experimental plants located in
the Duke Phytotron.

Experimental Design

The experiment was designed as a 4 x 4 factorial. Four day
temperatures and four night temperatures were used. The factorial
design allowed for complete statistical analyses on the data obtained.
The temperature combinations are presented in Table 1.

Table 1. Experimental design of four night and four day
temperature treatments.

Day temperature		Night temperature
32		26
26		20
20	X	14
17		11

60

Temperature treatments were selected from a total of six night and six day temperatures available in the Duke phytotron glasshouses. Therefore, some restrictions were present on the choice of temperatures used. This restriction explains the fact that only three degrees separate the lowest day and night temperatures from the second lowest temperatures while six degrees separate all other temperature treatments. Throughout the remainder of this dissertation, all temperatures will be listed in a format with day temperature first followed by night temperature in degrees Celcius (i.e.,day/night) (ex.,32/26).

Twelve plants were grown at each of the sixteen day x night temperature regimes. Four of these plants were harvested at each of three harvests. The three harvests and criteria used for determining harvest time are presented in Table 2.

Table 2. Criteria used in determining harvest dates.

Harvest	Criteria
First	The beginning of bloom in the various treatment regimes.
Second	The end of bloom in the various treatment regimes.
Final	Estimated date of treatment maturity.

Identical measurements were made on second and final harvest plants. The first harvest, due to the age of the plants, had only vegetative and no reproductive measurements taken. The data measurements taken are presented in Table 3.

Various other variables were created using several of the measurements (variables) in Table 3. These are:

1. Root dry weight percentage of total dry weight.

2. Stem dry weight percentage of total dry weight.

3. Leaf dry weight percentage of total dry weight.

4. Mature pod dry weight percentage of total pod dry weight.

5. Mature pod number percentage of total pod number.

6. Total reproductive dry weight percentage of total dry weight.

Table 3. Data measurements taken on three harvests.

Measurements	First Harvest	Second Harvest	Final Harvest
Root dry weight	X	X	X
Stem dry weight	X	X	X
Leaf dry weight	X	X	X
Total dry weight	X	X	X
Mature pod dry weight		X	X
Mature pod number		X	X
Total pod dry weight		X	X
Total pod number		X	X
Total reproductive dry weight		X	X
Length of the germination period			
Length of the vegetative period	X		
Total length of development through the vegetative period	X		
Length of the flowering period		X	
Total length of development through the flowering period		X	
Length of the filling period			X
Length of the total growth period			X
Mainstem height			X

Experimental Conditions

Glasshouses

Four of the six glasshouses at the Duke phytotron were used. The exterior of these glasshouses can be seen in Fig. 1. Figure 2

shows the interior of one glasshouse with a variety of plants under experiment and four of the sixteen temperature treatments of this experiment. These glasshouses are constructed so as to maintain critical temperature control, provide even light distribution, and facilitate easy transport of experimental plants. The Phytotron Procedural Manual (Downs and Bonaminio, 1976) and Kramer et al. (1970) explain the construction of these units and provide technical information. Downs and Hellmers (1975) also provides information on phytotrons and phytotronics.

Period of Treatment Application

The temperature treatments were applied for the total duration of the experiment from germination until final harvest as continual treatment application provides the best results on the effect of temperature upon total plant development and growth. Various plant growth stages affect one another as discussed in the review of literature. Gipson et al. (1979) discovered that, in sorghum, there were no temperature effects on yield components when the treatments were terminated at bloom; these effects became apparent when applied from emergence to maturity.

Temperature

The glasshouses are controlled to ±½° C. Temperature is maintained through a series of thermocouples which are responsible for activation of control circuits on large, glycol cooling units and steam heating units. Operation information can be obtained from Downs and Bonaminio (1976).

Fig. 1. Photograph of the exterior of the glasshouses at the Duke University Phytotron showing glasshouse construction and four peanut temperature treatments.

Fig. 2. Photograph of the inside of one glasshouse showing four peanut experiment treatments, assorted other experimental plants, carts used in plant transport, and roof water used for cooling and light dispersion.

Humidity

Fortanier (1957) found humidity to act differently on various
plant parts. Low humidity adversely affected such factors as leaf
number and stem length. Fortanier found the effect was more pro-
nounced when combined with low soil moisture.

While humidity was not strictly controlled in the glasshouses,
it was always at least 70% and usually more as measured by an aspirated
thermocouple psychrometer. Low humidity,therefore,was not a limiting
factor in any experimental treatment.

Daylength and Radiation

For this research, the glasshouses were chosen for use instead
of growth chambers since allowing the plants to grow under natural
radiation intensity and daylength provides more reliable results
than obtainable under artificial lighting. Incoming solar radiation
was measured using a standard integrating electronic pyranometer
that measured in accumulated Langleys per day. These data were trans-
formed to megajoules per day and are presented in Fig. 3 as five day
averages to reduce variability. Durham, N. C., is located approx-
imately 36°00' N latitude and 78°55' W longitude. The daylength
for this location is presented as five day averages in Fig. 4. The
daylength was calculated using a time of sunrise/sunset program on
a programmable calculator (Anonymous, 1976b).

Radiation and daylength (as a factor in total radiation) possibly
played important roles in this experiment. These roles will be dis-
cussed later.

Fig. 3. Incident solar radiation at Durham, N. C., for average five day periods during the years 1976-1977.

Fig. 4. Hours of sunshine at Durham, N. C., for average five day periods during the years 1976-1977.
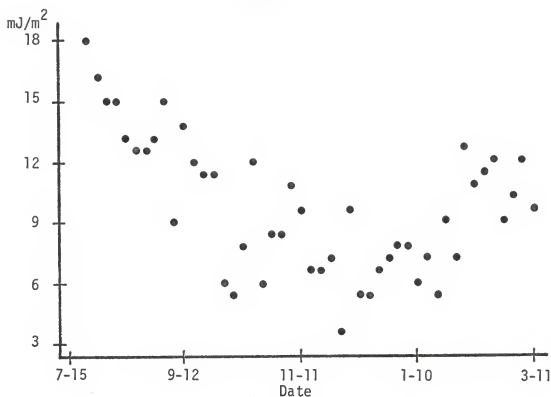
Watering and Fertilization

All plants were fertilized with approximately one-half strength Hoagland's solution at 10:00 a.m. each day. The composition of this solution is given in Table 4. The chemicals were mixed with deionized water. All plants were watered with deionized water at 3:00 p.m. each day. In some of the warmer temperature treatments, such as 32/26, a third mid-day deionized watering was needed to prevent wilting of the plants. In studying three periods during pod and peg formation, Fortanier (1957) concluded that high soil moisture is desirable and leads to an increase in pegs and pods as well as an increase in the percentage of pods arising from pegs.

Several of the cooler treatments (especially night temperature) experienced fungal disease caused by excess moisture on the plants throughout the night. On these treatments, the 3:00 p.m. watering was found to be unneeded and was discontinued.

Water and nutrient solution was applied mainly by hand through a hose and sprinkler system. A few treatments that remained in the same glasshouse for the duration of the experiment were fitted with an automatic drip-type watering system. In all cases the pots were supplied with water or nutrient solution until excess was flowing from the escape holes on the pot bottom.

Pots and Potting Material

Plastic pots 25 cm in diameter were used for single plant growth. The potting substrate was a 1:1 mixture of vermiculite and 6 mm washed quartz gravel. The gravel was steam sterilized before mixing with the vermiculite. All pots were filled with substrate to ½ cm below the pot rim to allow for settling and maximum root growth.

Table 4. Composition of the nutrient solution used at the Duke
University phytotron (approximately one-half strength
Hoagland's).

Chemical	Grams per liter Stock solution	Working Solution (ppm)	
	"A" Solution*		
1. Calcium nitrate	236.2	Ca	80
		N	56
	"B" Solution*		
2. Potassium phosphate	34.25	K	19.63
		P	15.53
3. Potassium nitrate	126.65	K	98
		N	35.1
4. Magnesium sulphate	126.65	Mg	24.9
		S	32.9
5. Sequestrene (330 Fe DTPA)	38.44	Fe	10
6. Zinc sulphate	.056	Zn	.025
		S	.012
7. Manganous sulphate	.391	Mn	.254
		S	.148
8. Copper sulphate	.021	Cu	.011
		S	.055
9. Boric acid	.725	B	.254
10. Molybdic acid	.005	Mo	.005
11. (MoO_3 - Anhydrous)	.004	-----------	
12. Ammonium nitrate	50	N	35
13. Ammonium phosphate	29	P	15
		N	7
14. Sodium chloride	5.85	Na	4.6
		Cl	7.1

*One part of solution A and one part of solution B are added to 500
parts water. Chemicals 2 through 11 are a commercially prepared
mixture.

As plants became larger, it became obvious that the 25 cm pots would not provide the area needed for complete pegging and pod set of the plants. Zamski and Ziv (1976) state that the proembryoes at the tip of the peg control its elongation. While darkness was found to be an essential factor for induction of pod formation, they also found mechanical stimulus is needed for normal thickening and diageotropic orientation of the pod. Therefore, boxes measuring 56 cm per side and 13 cm in depth were made from quarter-inch plywood. The boxes were constructed so as to fit around the pots with their surfaces level with that of the pots. The same gravel-vermiculite mixture used for the pots was used to fill the boxes to the same height. Holes in the boxes allowed for drainage of excess nutrient solution. These boxes were watered with nutrient solution (described earlier) once every other day.

Germination Procedure

All plants were germinated at the temperature treatment that they would be in for the duration of the experiment. This procedure was also used by De Beer (1963). Fortanier (1957) states that generative development starts together with germination. Therefore, the effects of temperature on this period need to be considered.

Four seeds were placed in each pot at a depth of 5 cm. This is approximately the recommended field planting depth and was considered to be sufficient in this experiment to prevent drying of the seeds in the warmer treatments. The final depth may have been somewhat more than 5 cm since some settling and shifting of the substrate due to cart movement occurred. Fortanier (1957) found the

time of first flowering to not be affected by planting depth but the total number of flowers was affected. If the seeds are planted too deep, Fortanier says, the more cotyledonary branches are lost or develop poorly causing loss of flower numbers.

Some of the cooler night temperature treatments experienced difficulties in extending the hypocotyl above the substrate surface. Difficulty in hypocotyl extension occurred in the 32/11 and 26/11 plants and apparently was due to the high temperature differential affecting the geotropic mechanism. A number of seeds produced one, two, or three 360° circles with their radicals before the seedlings emerged above the substrate surface. Several seeds never were able to grow in the correct direction. Lyons (1973) states that tropical and subtropical plants exhibit a marked abnormal physiological function when exposed to nonfreezing temperatures below 10 to 12 C. He called this "chilling injury."

The 32/11 and 32/14 treatments also experienced moderate to severe leaf burning and defoliation as soon as the first tetrafoliate leaves appeared above the substrate surface. This condition caused the loss of several seedlings in some pots and necessitated transplantation of more vigorous seedlings from other pots of the same temperature treatment. The burning and defoliation apparently was brought about by the desiccation action of transferring the young seedling plants from a night temperature of 11 or 14 C to a day temperature of 32 C within a ten minute period. There was no intermediate adjustment period. It was noted later in the experiment that both of the above mentioned treatments experienced moderate wilting upon placement

in the 32 C day temperature glasshouse. This wilting would disappear in one to one and one-half hours after transfer. The scorching of the two treatments' plants retarded growth slightly but the plants quickly recovered.

After the seedlings had reached a sufficient size to allow for estimation of their vigor and before they interferred with each other's growth, they were thinned. Only the most vigorous seedling was left in each pot.

Variety

The Florunner variety of peanut (_Arachis hypogaea_ L.) was used in this experiment. The primary reason for the choice of this variety is that it is the most commonly grown runner variety in the southeastern United States (Norden et al., 1969). Almost 100% of peanut acreage in Florida is planted with Florunner while in other states the percentages are greater than 90%.

Florunner is a runner variety with a prostrate growth habit and a sequential branching pattern typical of Runner and Virginia type varieties. Florunner was selected from a cross between the varieties Early Runner and Florispan. The economic importance of this variety to the Southeast makes it the variety of choice for research directed towards increasing yield.

Harvesting Technique

Although the experiment was designed for three harvests, experimental difficulties with the first harvest plants as well as the large variation in measured indices of these plants precluded the

use of this harvest's results. An attempt was made to gather first harvest information by replanting some treatments. But, lower radiation intensities and factors associated with this reduction in intensity produced plants which showed different characteristics than the original treatments. Therefore, only the second and final harvests are presented in the later discussion.

The highest within-treatment variation occurred in the first harvest plants and the lowest in the final harvest plants. The variation was an artifact of sampling procedures. In order to minimize variation and provide the best statistical test for the final harvest plants, the two smallest and the two largest plants were chosen for harvest at the first harvest. The same procedure was used for the second harvest except that in some treatments only one or less plants existed at either end of the size spectrum. With a small number of plants it is impossible to use a completely random method of choosing harvest plants and at the same time expect precise statistical tests.

All plants were removed from their pots and washed to completely free them from foreign matter. Special care was given the plant roots to free them from gravel and vermiculite. The various plant parts were then separated and bagged for measurements and drying. Since the phytotron reduces disease problems and because the plants were grown in pots, almost all vegetative and reproductive matter produced by the plants was recovered for analysis.

Disease and Pest Control

While the phytotron is exceptionally free of pests and diseases, conditions in certain treatments were extremely conducive to the growth and spread of certain pathogens. Diseases and pests were

selectively controlled on a treatment-by-treatment as well as plant-by-plant basis using various cultural practices and chemical applications. Under some treatment conditions, fungal stem diseases spread so rapidly as to destroy various plant stems before treatment could be applied. In order to not lose experimental plants, these stems were pruned and the plants appeared to recover nicely. No data anomalies were noted in affected plants at harvest time.

Fortanier (1957) has conducted the most comprehensive work on the effects of stem removal. He found branching pattern to be affected only slightly by stem pruning. In his literature review, Fortanier listed several authors who found that removal of one or more cotyledonary branches or parts thereof affected flowering and sometimes yield adversely. He discovered mainstem removal at the second leaf caused less flowers, pegs, and fruits to be formed possibly due to a loss of assimilation area. Fortanier (1957) postulated that the lower number of pegs and pods might be due to the absence of pegs and pods that would normally have been formed on the mainstem had it not been removed. In a few cases, though, the pruning of the mainstem actually increased the number of flowers but decreased the yield of pegs and pods. Mainstem removal did not appear to increase the number of side stems. Apparently, one of the side stems develops vigorously and takes the place of the mainstem, thus restoring the plant to its original condition (Fortanier, 1957).

Daylength and Light Intensity

While all treatments were subjected to the same daylength and light intensity conditions in the glasshouses, maturity and final harvest date of various treatments varied causing some treatments

to continue growing under reduced radiation and daylength. Radiation and daylength were shown earlier in Figs. 3 and 4.

De Beer (1963) found plants receiving more radiation and a longer photoperiod to have better proportional development. Little effect of light on leaf number was noticed by Fortanier (1957). He found daylength to not be of importance for mainstem length but he found a short photoperiod to give a better flower fertilization percentage because fewer flowers were produced. Cheliadinova (1944) also found the latter. Fortanier (1957) and Alegre (1957) found that lower temperatures gave better flower yields at lower light intensities. There is no influence of photoperiod on the time of first flowering but the number of flowers, intensity of flowering, and fruit formation were affected (Cheliadinova, 1944; Fortanier, 1957). A longer photoperiod gave more flowers but less fruit (Fortanier, 1957).

Cheliadinova (1944) found that flowering in short-day treated plants varied according to temperature. Alegre (1957) showed that a peanut variety grown at normal temperatures had lower flowering at shorter daylength but this daylength showed no effect when the normal temperature was applied only at night.

An (1978) studied the effects of low light intensities on the peanut. She found various detrimental effects including lower yield, lower average fruit weight, and reduced flowering. Her research, though, did not include effects of temperature.

Dr. J. H. Williams (personal communication; Crop Breeding Institute, Salisbury, Rhodesia) has found that lower light intensities reduced the differences found between different temperature treatments. As the amount of radiation increased, he found larger differences.

The findings by Williams would indicate that treatment differences at low radiation might be masked by normal variation while the differences at high radiation would show greater significance.

Seed and Pod Maturity

Many authors have used various methods in an attempt to ascertain the time that the peanut plant reaches maturity. Almost all of these methods involve the seed or pod. Some authors have used the pigmentation of the internal pericarp as a classification basis (Collins and Matlock, 1966; Dickens, 1957; Emery and Gupton, 1967; Mills, 1964; Pickett, 1950; Schenk, 1961; Smith, 1954; Toole et al., 1964). A shell with a dark, mottled interior is considered to be a sign of pod maturity by the above authors.

Wood (1968) classified pegs into classes depending upon enlargement of the ovule. Mills (1964), Pickett (1950), and Toole et al.,(1964) used pericarp color along with other visual and textural differences. Smoothness of seed coats was felt by Emery and Gupton (1967) to be an accurate index when applied during certain growth periods. Jackson (1967) discovered that a progressive decrease in surface area of the pod occurs during maturation until a minimum is reached. Collins (1966) used mean individual seed weight for his maturity predictor.

An organoleptic test used by Dickens (1957) found immature seeds to have more off-flavor than dark or splotched pericarp pods. Gupton (1968) concluded that the best method to index pod maturity from a known growth period is the percent of light transmittance through the expressed oil. The latter method is for late maturity pods while a seed cutting method is felt by Gupton to be best for young pods.

There are many drawbacks to many of the maturity methods. Davis
(1968) states many methods are time-consuming and unreliable. Good
harvest prediction is difficult, he states, due to the indeterminant
habit of the peanut. Emery and Gupton (1967) indicate that pericarp
discoloration is not accurate under all growth periods. Collins
and Matlock (1966) found two of their pigmentation classes behaved
the same in later chemical tests.

In this research a method of indexing pod and pegs was used
that included both size and physical characteristics. The method
was similar to that of Gregory et al. (1951, 1973) and is shown in
Table 5.

Table 5. Peg and Pod Categories

Category	Description
1	Aerial pegs.
2	Pegs attached to pods.
3	Aborted pegs and pods.
4	Pegs entered into soil. White tips but no ovary swelling.
5	Slightly swollen ovaries. No constriction formed between first and second ovules; little seed fill.
6	Intermediate pod. Constriction formed between first and second ovules; little seed fill of the second ovule (distal end); variable seed fill of the first ovule; distinct veination not yet formed on the distal end of shell (immature shell).
7	Slightly immature pod. Distinct veination formed over entire pod surface; advanced fill of both ovules; parts of shell still soft to pressure; intervein areas not yet distinct.
8	Fully mature pod. Distinct veination over entire pod surface; complete fill of all ovules present except in cases of aborted second ovule; shell does not yield to pressure; intervein areas collapsed and veination remarkably distinct.
9	Shriveled (aborted or diseased) pod.

Not all of the classes listed will be presented in this dissertation. Category #1 is not of major importance. Category #2 is a recount of total pod number. The weight of the pegs is included in analyses of the weight of the reproductive portion of the plants. While categories #3 and #4 are of interest, they will not be presented in this dissertation. Categories #5, #6 and #7 were found to be quite variable. These categories will be discussed as one since they are the antithesis of mature pod weight and number. Category #9 will not be presented. While Gregory et al. (1951, 1973) used shrinkage upon drying as a criterion for distinguishing his last two categories, this was not done for the purposes of this research. It is believed that few mistakes were made by exclusion of this criterion. All maturity determinations were performed by the same technician in order to remove technician error.

Growth Period Timing and Estimation of Plant Maturity

As stated earlier, the first two harvests were performed at the beginning and end of bloom. The end of bloom criterion worked well in all cases except for the 20/20, 17/20, and 32/11 treatments. The latter treatments never exhibited complete end of bloom and,therefore,eight plants were harvested at the conclusion of the experiment with no actual second or final harvests. These treatments were included in both the second and final harvests' statistical analyses.

Final maturity for the other treatments was calculated from the growth period timings normally observed for Florunner peanuts in Florida. Bloom normally occurs at about day 28 after planting. Bloom normally ends about day 78 with final maturity occurring between day 135 and 138. The 32/26 treatment followed these dates exactly

with other treatments varying in delay. An extrapolation from the number of days of delay of germination and begin bloom was used to roughly estimate final harvest dates. End of flowering was not used as in many cases this period lasted for an extremely long time. The period of flowering is at least partially controlled by fruit number (Fortanier, 1957; Hull, 1930; McCloud, 1974; Smith, 1954; Wood, 1968). The increase in pod number was so slow in a number of cases as to prolong flowering for a lengthy period. In normal field harvest practice, a "best" date for harvesting has to be chosen since not all pods will be mature at harvest. Delaying too long causes a loss of mature pods. An estimation regardless of end of bloom was needed to prevent the loss of pods that had formed at the beginning of bloom. An exact estimate was not possible and extra plants were not available for pulling as would be the case under field conditions.

Both Fortanier (1957) and Sturkie and Williamson (1951) found that yellowing of the foliage, spotting of the leaves, and leaf drop are indicators of the time of maturity. The latter indicators were found in several of the treatments (notably 32/20) in my experiment where full and heavy pod loads were obtained. In a few of these cases, the visual factors took precedence over the calculated maturity dates and caused earlier than estimated harvests. However, since all treatments did not exhibit visual criteria, they could not be used as set harvest criteria. The visual indicators acted as a check on the extrapolation method used.

Terminology

Throughout the results and discussion the words fruit and pod will be used interchangeably. Seeds will be called seeds and not kernels as is the case in much of the literature. Peg and gynophore are both used in the literature. In this discussion only the term peg will be used. Smith (1950) states that the peg is morphologically an elongation of the ovary and therefore is not a gynophore. Leaflet will be used for the four subleaves of each tetrafoliate leaf. The term leaf will be used for the four leaflets excluding petiole, and petiolules.

Harvest and Measurement Procedures

Upon plant harvest, all plant parts to be measured were separated for further analysis. Some measurements were made prior to drying. The methods used for various measurements are given below. In all cases final dry weights were taken on plant samples dried in a forced-air oven at 65-70 C for a period of time needed to bring the sample to dryness. In no case was this period of time less than forty-eight hours. All weighings were made on an electronic analytical balance to 1/100 of a gram.

Root Dry Weight

Roots were removed from the 25 cm pots. They were separated from the rest of the plant at the junction with the hypocotyl. Vermiculite and gravel was removed and the roots were dried and weighed.

Stem Dry Weight

Stems were considered to be the remainder after pod, peg, root, and leaflet removal. That is, this portion also included petioles and petiolules of the leaves.

Leaf Dry Weight

All leaflets were removed excluding petioles and petiolules.

Total Dry Weight

Total dry weight was calculated from the sum of root, stem, leaflet, peg, and pod dry weights.

Mature Pod Number and Dry Weight

Pods in category #8 (as discussed earlier) were removed from the plant and the pegs removed. They were then counted, dried and weighed.

Total Pod Number and Dry Weight

All pods from categories #5 to #9 (as discussed earlier) were removed from the plant and attached pegs removed from the pods. The pods were then counted, dried, and weighed.

Total Reproductive Dry Weight

The sum of the total pod weight and the total peg weight equals the total reproductive weight. This variable is inversely related to the total vegetative weight and, therefore, the latter is excluded from discussion. The two quantities would have identical statistical evaluations.

Procedures for Determination of Growth Period Lengths

Length of Germination Period

Germination was considered to have occurred in each treatment when at least one seedling had emerged in at least three-fourths (nine) of the pots. The number of days from planting equaled germination length.

Length of Vegetative Period

The length of the vegetative development period was obtained from subtracting the germination period length from the number of days to begin bloom.

Length of Flowering Period

The point at which each treatment ended bloom was considered to be when three-fourths (six) of the eight pots produced less flowers than five percent of the average highest flower count for each pot. When the latter occurred for three consecutive days, end of bloom had occurred. The three day limitation was used because of environmentally as well as internally induced flower count variation as discussed under the Review of Literature section "Flowering Periodicity." The difference between the number of days to end bloom minus the number of days to begin bloom is the length of the flowering period. Three treatments (17/20, 20/20 and 32/11) never actually stopped blooming or reached maturity. Therefore, the length of their flowering period as well as that of filling and total growth was determined by termination of the experiment.

Length of Filling Period

The length of the filling period was obtained by subtracting the number of days to the start of flowering from the number of days to the date selected for final harvest. While the first flowers may not produce pods and pegs take a variable amount of time to enter the soil, the beginning of bloom was used as the starting date. An exact date of first peg penetration and pod formation was not obtained.

Mainstem Height and Created Variables

Mainstem Height

All plants were not measured for this factor. This data was obtained from the measurement of the length of a single "average" plant's mainstem from each treatment. Therefore, differences should not be regarded as statistically significant. These data are included to show the effect of temperature on plant growth habit.

Root Dry Weight Percentage of Total Dry Weight

This variable was calculated by dividing the dry weight of the roots by the total dry weight of the plant.

Stem Dry Weight Percentage of Total Dry Weight

Dividing the dry weight of the stems by the plant's total dry weight provided stem weight percentage.

Leaf Dry Weight Percentage of Total Dry Weight

Leaf weight percentage was obtained by dividing the leaf dry weight by the total dry weight of the plant.

Mature Pod Number and Dry Weight Percentages of Total Pod Number
and Dry Weight

The mature pod number (category #8 of Table 5) was divided by
the total number of pods produced to obtain the mature pod number
percentage. The same procedure was used with weight to find mature
pod dry weight percentage.

Total Reproductive Dry Weight Percentage of Total Dry Weight

This variable was calculated by dividing the total reproductive
weight (total peg weight + total pod weight) by the total dry weight.
The total vegetative weight percentage would be inversely proportional
and would show the same statistical results.

Variable Name Truncation

All of the calculated percentage variable names will be truncated
in the Results and Discussion after the word percentage.

Statistical Analyses

All statistical analyses were performed at the Northeast Regional
Data Center of the State University System of Florida. The center is
located at the University of Florida, Gainesville, Florida. The
analyses were produced using the procedures of the Statistical Analysis
System (SAS) of the SAS Institute, Inc. The 1976 version of SAS was
in effect during data evaluation although several variations, through
76.6D, of this version were used. The procedures are listed in Barr
et al. (1976) and Helwig (1977).

Analysis of variance was performed using SAS's General Linear
Models procedure. Correlations were performed using SAS's Correlation

Procedure. A discussion of these analysis procedures can be found in Snedecor and Cochran (1967) and in references listed by Barr et al. (1976) and Helwig (1977). Duncan's Multiple Range Test (MRT) was used for evaluating statistically significant differences among the means of the various treatments.

There were unequal subclass numbers in the treatments of this experiment. The unequal subclasses were adjusted for automatically by SAS procedures using Kramer's adjustment for Duncan's (MRT) (Chew, 1977; Kramer, 1956) and by using the General Linear Models procedure. Duncan's (MRT) was used to separate means by night temperature and by day temperature. While Duncan's (MRT) was developed specifically for analysis of variance and factorial designs, it was not designed to separate means of multiply classified data. Nevertheless, SAS procedures allow separation of multiply classified data. A separation and ranking of all treatment means is useful. Therefore, Duncan's test was used for this separation as no other procedure was deemed to be more valid for this experiment.

Statistical Analysis System has recently produced a procedure to better separate means of unequal subclass treatments. Unfortunately, most data for this research were already analyzed before this new procedure was added to SAS. Therefore, Duncan's (MRT) was used in the remaining analyses in order to have consistency of analysis.

RESULTS AND DISCUSSION

Although the majority of analyses was performed on the basis of
separate day, separate night, or separate treatment combinations, it
is of interest to note the mean temperatures for each of the sixteen
temperature treatments. Since almost all factors studied showed high
day vs. night temperature interaction, analysis using mean temperatures
would neglect the very important effect of diurnal temperature variation
as well as possibilities for thermoperiodic effects. Diurnal variation
is especially important where day and night temperatures were quite
divergent but the mean temperatures were the same or almost so
(Table 6). Therefore, all analyses were performed using separate
day and night temperatures.

Developmental Period Lengths

As was shown in the Review of Literature, temperature greatly
affects the length of the phenologic growth periods of crop plants.
The peanut is no exception. The following discussion deals with the
effect of temperature on four separate growth periods of the peanut
plant and the combination of these as expressed through the life
cycle length of the plant.

Length of Germination Period

The number of days from planting to the germination of each of
the treatments is presented in Table 7. Of primary interest is the

Table 6. Mean temperatures and ranking for the sixteen temperature
          treatments.

Treatment	Mean	Rank		Treatment	Mean	Rank
32/26	28	1		20/26	24	3
32/20	24	3		20/20	20	6
32/14	20	6		20/14	16	9
32/11	18	8		20/11	14	11
26/26	26	2		17/26	23	4
26/20	22	5		17/20	19	7
26/14	18	8		17/14	15	10
26/11	16	9		17/11	13	12

Table 7. Length of the germination period.

Treatment	Days	Rank		Treatment	Mean	Rank
32/26	8	2		20/26	7	1
32/20	12	6		20/20	11	5
32/14	15	9		20/14	14	8
32/11	16	10		20/11	16	10
26/26	7	1		17/26	8	2
26/20	9	3		17/20	10	4
26/14	12	6		17/14	17	11
26/11	13	7		17/11	18	12

low variation in values for the four day temperatures within each night temperature (Fig. 5). The largest deviation is found in the case of the 26/14 and 26/11 treatments where germination was slightly faster and the 17/14 and 17/11 treatments where germination was slightly slower than the other 14 and 11 C night temperature treatments. Night temperatures within each day temperature are nearly linear in their effect (Figs. 6 and 9). It appears that a high day temperature (32 C) as well as a low day temperature (17 C) was not as conducive to germination as the intermediate day temperatures (Fig. 9). The fastest germination occurred at a day temperature of 26 C for each night temperature.

Night temperature has the largest effect upon the length of germination. A correlation coefficient of -.92 (P=.0001) between night temperature and days of germination was calculated. A non-significant correlation coefficient of .08 was found for day temperature. The greater influence of night temperature exhibited for the germination period length will be seen throughout much of the data of my research. How much of the increased night temperature effect is due to its duration of sixteen hours vs. eight hours for day temperature is questionable. Certainly some of the effect must be attributed to this difference in length of treatment.

The maximum day/night differential was 21 C in the 32/26 treatment. Fortanier's (1957) statement that development is determined by mean daily temperature as long as the range is not in excess of 20 C is partially supported by this research. Mean temperatures showed a correlation coefficient of -.85 (P=.0001). While not as high as that for night temperature, the coefficient is still quite

significant. The high significance of mean temperature indicates
that most of the increased night temperature effect was indeed caused
by its increased duration. Nevertheless, there is enough difference
between the rankings of the two tables to indicate that there is some
differential effect between day and night temperatures.

Seven of the sixteen treatments had temperatures below the 18 C
mean cardinal temperature for germination listed by Bolhuis and De
Groot (1959) and Mixon et al. (1969). The data of this research
contradict their findings since both germination and further
development was found at the lower temperatures. This disagreement
might be partially due to the almost nonlimiting conditions that
the plants were grown under in the phytotron. Also, most other
research has been conducted with constant temperatures as opposed
to the varying day/night regime in my research. Mroginski and
Krapovickas (1971) found alternating temperatures to be better for
germination while Montenez (1957) concluded the opposite.

De Beer (1963) found mean temperatures between 24 and 33 C to
not have a large effect on the length of germination. Bolhius and
De Groot (1959) showed the same for 27-30 C. Toole et al. (1964)
found the best germination to be between 22.5 and 30 C while Mills
(1964) observed the greatest response between 24 and 27 C. In my
experiment, only six treatments (32/26, 32/20, 26/26, 26/20, 20/26,
17/26) had means above 22 C, but these tend to substantiate the above
authors' findings. De Beer (1963) found fastest germination at 27 C.
The latter was not found in my study. Montenez (1957) and Catherinet
(1959) found 33 C to be optimum. The highest mean temperature studied
in my research was 28 C. The lower the temperature, the longer the
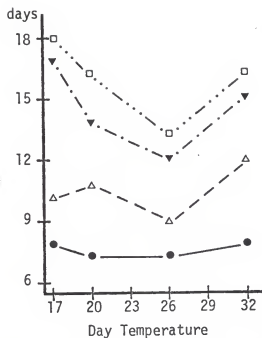
Fig. 5. Length of germination period by day temperature.
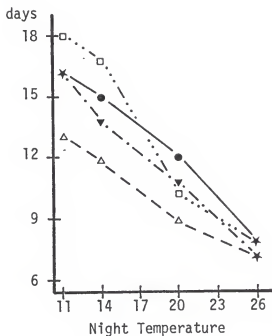
Fig. 6. Length of germination period by night temperature.

| ● = 26 C | △ = 20 C | ▼ = 14 C | □ = 11 C night | ★ = several points |
| ● = 32 C | △ = 26 C | ▼ = 20 C | □ = 17 C day | |
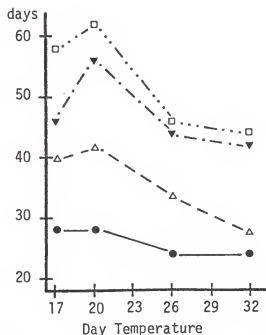
Fig. 7. Length of vegetative period by day temperature.
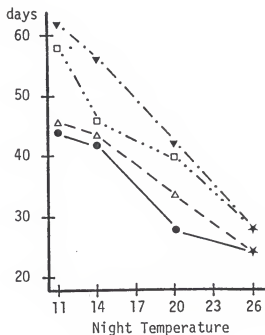
Fig. 8. Length of vegetative period by night temperature.

delay between planting and appearance of the cotyledons above the soil surface as found in my study, by De Beer (1963), and by Bolhuis and De Groot (1959).

Length of the Vegetative Period

Again, night temperatures within each day temperature show a nearly linear relation (Figs. 8 and 10). A 20 C day temperature appears to lengthen this period regardless of night temperature (Figs. 7 and 10). The average day temperatures (Fig. 10) show a somewhat different relation than that found for germination (Fig. 9) but their correlation still does not show significance.

From Table 8 it can be seen that the rankings remain similar to those found in Table 7. However, of note is the slight upward movement in ranking of the warmest day temperature (32 C) plants while the 26, 20, 17 C day plants decreased slightly in ranking except for the 17/14 and 17/11 plants. Nevertheless, there is a close correlation between the period ranking and the total rankings indicating no major shift in developmental trends between the first two periods of development. The correlation coefficient found for these two rankings is r=.99 (P=.0001).

Bolhuis and De Groot (1959) found no growth or development to occur below a constant temperature of 20 C and they found 24 C to be too low for adequate growth. Ten of the sixteen treatments in my experiment had mean temperatures below or at 20 C. All showed continued growth and all bloomed indicating further development. Mills (1964) and Emery et al. (1969) found a base temperature of 13.3 C in work with temperature combinations. This value is more

Table 8. Days from germination to flowering onset, total experimental
days to flowering onset and date of first harvest.

Treatment	Days	Rank	Total Days	Total Rank	Harvest Date
32/26	23	1	31	1	8/13/76
32/20	28	4	40	3	8/22/76
32/14	41	7	56	8	9/7/76
32/11	44	9	60	10	9/11/76
26/26	24	2	31	1	8/13/76
26/20	34	5	43	4	8/25/76
26/14	43	8	55	7	9/6/76
26/11	45	10	58	9	9/9/76
20/26	28	4	35	2	8/17/76
20/20	41	7	52	6	9/3/76
20/14	56	12	70	12	9/21/76
20/11	62	14	78	14	9/29/76
17/26	27	3	35	2	8/17/76
17/20	40	6	50	5	9/1/76
17/14	46	11	63	11	9/20/76
17/11	57	13	75	13	9/26/76

comparable with my experiment as 13 C was the lowest mean temperature
and the treatment with this mean showed only minimal development (Figs.
32, 35, 69, 70, 71, and 72). Fortanier (1957) found a base of 20 C as
an average of day/night temperatures. A base minimum temperature of
6 C was determined by Cox and Martin (1974).

Average temperatures below 23 C increase the number of days to
first flower from time of germination (Bolhuis and De Groot, 1969).
Table 8 shows a large increase in days to flowering in treatments with
means less than this temperature. Cheliadinova (1944), Jacobs (1951),
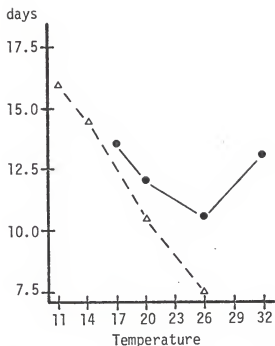
Fig. 9. Length of germination period by day or night temperature group.
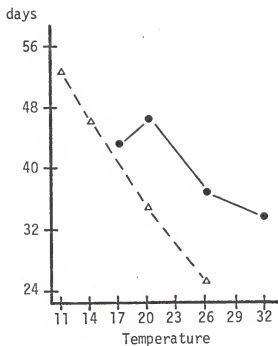
Fig. 10. Length of vegetative period by day or night temperature group.

● = day temperature;   △ = night temperature;   ★ = several points
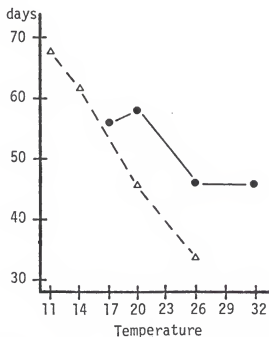
Fig. 11. Total length of development through the vegetative period by day or night temperature group.
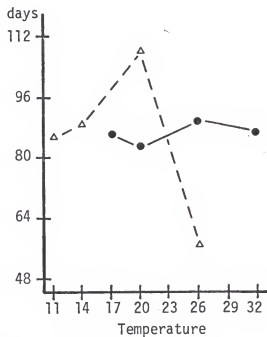
Fig. 12. Length of flowering period by day or night temperature group.

and Ono et al. (1974a) all state that warmer temperatures produce earlier flowering. Fortanier (1957) indicates that a maximum-minimum temperature differential of 20 C is maximum for flowering. In my experiment, flowers were still produced in the 32/11 treatment. Fortanier also concluded that as long as the difference is less than 10 C, the mean temperature is of primary importance. This statement is partially supported in this experiment as the rankings in Table 8 follow closely the mean temperature rankings in Table 6. The mean temperatures were found to be correlated well with both the days of vegetative development (r=-.95, P=.0001) and total developmental days (r=-.96, P=.0001). These findings do not support Fortanier's 10 C limitation.

Day temperature showed no effect on the vegetative period's length (as was also the case with the germination period) with an r-value of -.37 (P=.16) (Figs. 7 and 10) and on the total days of growth (r=-.31, P=.24) (Figs. 13 and 11). Night temperature was highly correlated to the period length (r=-.88, P=.0001) (Figs. 8 and 10) and to the total days of development (r=-.91, P=.0001) (Figs. 14 and 11). Data in Fortanier (1957) states that at a low day or night temperature, the corresponding night or day temperature tends to have a major influence on the days to first flower. Figures 7, 8, and 10 and Table 8 indicate night temperature is of primary importance and greatly affects all day temperatures.

Length of the Flowering Period

Comparison of the total days of growth and days of flowering (Table 9; Figs. 15, 16, 17, and 18) shows that the correlation is
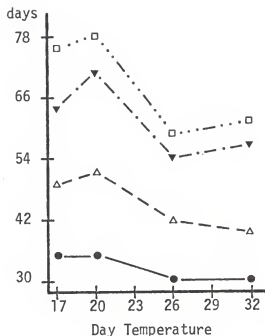
Fig. 13. Total length of development through the vegetative period by day temperature.
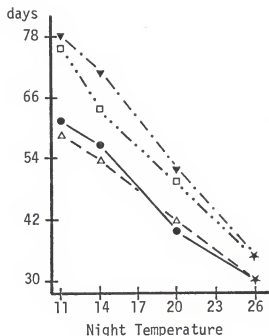
Fig. 14. Total length of development through the vegetative period by night temperature.

| ● = 26 C | △ = 20 C | ▼ = 14 C | □ = 11 C night | ★ = several points |
| ● = 32 C | △ = 26 C | ▼ = 20 C | □ = 17 C day | |
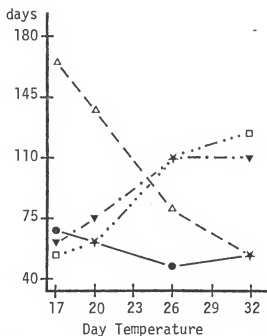
Fig. 15. Length of flowering period by day temperature.
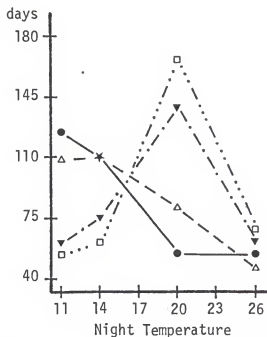
Fig. 16. Length of flowering period by night temperature.

not as large as that between total days of growth and the length of
the vegetative period. Nevertheless, the correlation is still highly
significant r=.93 (P=.0001). Looking at the days of flowering (Figs.
15 and 16) and their ranking (Table 9) shows that the reason is the
increased developmental speed of the coolest treatment plants to the
point where they are similar to the warmer treatments. The lines
cross each other in Figs. 15 and 16 instead of following similar
patterns as in earlier figures. This crossover indicates a marked
change in developmental effects of temperature in the cooler treat-
ments. The 17/11, 17/14, and 20/11 plants increased their rankings
considerably over those at the beginning of bloom. The coolest
treatments ended bloom in a similar length of time as the warmest
treatments. Length of flowering then increased from both ends of
the temperature spectrum until the middle temperature treatments of
32/11, 20/20, and 17/20 which never exhibited end of bloom criteria.

Because of the above relation, the correlations of mean tempera-
ture, day temperature, and night temperature (Fig. 12) to the length
of the flowering period are non-significant (r=-.21, r=.02, and r=-.25,
respectively). Mean temperature, day temperature, and night tempera-
ture correlations to the total length of development through flowering
show variable significances (Fig. 25). Mean temperature produced an
r-value of -.54 (P=.0294) while day temperature gave r=.10 (P=.7143)
and night temperature showed an r-value of -.56 (P=.0245). Day
temperature was non-significant. These relations for day and night
temperatures can be seen in Fig. 25.

The treatments were divided into two groups. The first was of
temperature treatments with 20 C or higher mean temperatures. The second
was of temperature treatments with 19 C or lower mean temperatures. These

Table 9. Length of the flowering period, total days of development, and the date of the second harvest.

Treatment	Days	Rank	Total Days	Total Rank	Harvest Date
32/26	56	4	83	2	10/4/76
32/20	56	4	96	3	10/17/76
32/14	110	12	166	11	12/26/76
32/11	127	14	187	13	none
26/26	49	1	80	1	10/1/76
26/20	84	10	127	7	11/17/76
26/14	112	13	167	12	12/27/76
26/11	107	11	165	10	12/25/76
20/26	61	6	96	3	10/17/76
20/20	135	15	187	13	none
20/14	75	9	145	9	12/5/76
20/11	60	5	138	8	11/28/76
17/26	67	8	102	4	10/23/76
17/20	166	16	216	14	mone
17/14	62	7	125	5	11/15/76
17/11	51	2	126	6	11/16/76

means (20 and 19 C) correspond to the two median treatments of 20/20 and 17/20.

After the data division, the correlations to flowering period length were -.87 (P=.0046), -.69 (P=.0582), and -.18 (P=.6656), for the treatments with 20 C or higher means, for mean, day, and night temperatures, respectively. For the group of treatments with means of 19 C or less, the correlations were .93 (P=.0008), .61 (P=.1067), and .37 (P=.3640), respectively. Of major interest is the marked non-significance of the day and night temperatures except in one case where day temperature showed minimal significance (6% level). However, the mean temperature values became highly significant after the division of data.
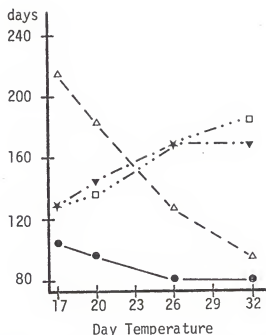
Fig. 17. Total length of development through the flowering period by day temperature.
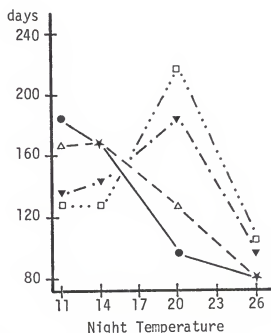
Fig. 18. Total length of development through the flowering period by night temperature.

| ● = 26 C | △ = 20 C | ▼ = 14 C | □ = 11 C night | ★ = several points |
| ● = 32 C | △ = 26 C | ▼ = 20 C | □ = 17 C day | |
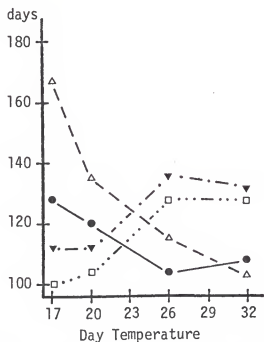
Fig. 19. Length of filling period by day temperature.
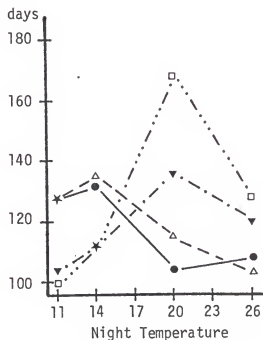
Fig. 20. Length of filling period by night temperature.

The 20 C or above group showed correlations to total days of development through flowering of -.90 (P=.0026), -.11 (P=.7864), and -.76 (P=.0299) for mean, day, and night temperatures, respectively (Fig. 25). The 19 C or below group gave r-values of .90 (P=.0024), .37 (P=.3654), and .59 (P=.1310), respectively. Day and night temperatures were non-significant for both groups except in one case where 3% significance was found. Mean temperatures increased in r-value from .54 to $\pm$.90. Correlation between the length of the flowering period and the total developmental length through flowering was .93 (P=.0001) before the data division and 1.00 (P=.0001) and .99 (P=.0001) for the first and second groups, respectively, after the division of data. The above values indicate that a fundamental change in the effect of temperature on plant development occurred during the flowering period.

Williams (1975) concluded that the duration of the reproductive phase is not well related to mean temperature. His data are in contrast to other Rhodesian authors (Crackett and Wall, 1971; Wilson et al., 1973) and my research which shows that a relation does exist. A number of authors (Fortanier, 1957; Stokes and Hull, 1930; Smith, 1954; Wood, 1968) state that the effect of temperature on the length of the flowering period is through the control of temperature on fruit numbers. No data are available from my research to support this theory. The fact that some treatments ended bloom whether or not they produced fruit indicates another mechanism is also present. The possibility of a second mechanism is especially indicated in the case of the coolest treatments that ended bloom as fast and abruptly as did the warmer

treatments. Where the warmer treatments' flowering is apparently
controlled by fruit number and therefore photosynthate supply
(as suggested by the above authors and McCloud (1974)), a mechanism
unrelated to fruit number is present in the cooler treatments. It
is possible that photosynthate supply is still the controlling
factor but is modified by something other than fruit number.

Length of the Filling Period

As stated earlier, the estimated date of maturity in some
treatments was calculated from the increase in length of the other
growth phases over that measured in "normal" field conditions.
This estimation was also used in treatments that produced no fruit.
In the latter treatments "filling period" is a misnomer. Three
treatments (32/11, 20/20, 17/20) never exhibited end of bloom cri-
teria and therefore never reached maturity. Because of the shortened
flowering period of the cooler treatments, it was difficult to esti-
mate the date of maturity since, up to the time of flowering the
growth period had been lengthening. Because of the latter diffi-
culty--as well as the problem of several treatments never ending
bloom, and the lengthy time needed to complete the estimated life
cycle of a number of the cooler treatments--termination of the
experiment began on day 175. The experiment termination proceeded
as rapidly as possible and in the order of the estimated date of
maturity of the treatments, except in the case of the three treat-
ments that showed no end bloom and where no estimate of maturity
date could be obtained.

In several cases, notably the 32/20 treatment, the estimate
of final maturity was superseded by subjective, visual observations.

Table 10. Length of the filling period, total days of plant growth,
and date of the final harvest.

Treatment	Days	Rank	Total Days	Rank	Harvest Date
32/26	107	4	138	2	11/28/76
32/20	105	3	145	3	12/5/76
32/14	132	12	188	10	1/17/77
32/11	127	9	187	9	1/16/77
26/26	104	2	135	1	11/25/76
26/20	117	6	160	5	12/20/76
26/14	136	13	191	11	1/20/77
26/11	129	11	187	9	1/16/77
20/26	119	7	154	4	12/14/76
20/20	125	8	187	9	1/12/77
20/14	112	5	182	8	1/11/77
20/11	104	2	182	8	1/11/77
17/26	128	10	163	6	12/23/76
17/20	166	14	216	12	2/14/77
17/14	112	5	175	7	1/4/77
17/11	100	1	175	7	1/4/77

In this treatment, yellowing of the foliage and general canopy
decline necessitated harvest before estimated maturity. Pod data
showed that maturity had indeed occurred. Apparently, total pod
filling speed had increased in this treatment due to an increase
in the rate of individual pod fill, a shorter flowering period
(causing full maturity over a shorter period of time), or a lower
total number of pods. Some or all of the latter factors may have
been involved. Which factors were involved was not discernable
in this research.
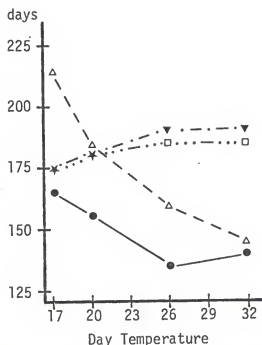
Fig. 21. Total length of development through the final harvest by day temperature.
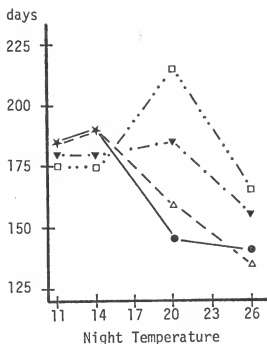
Fig. 22. Total length of development through the final harvest by night temperature.

| ● = 26 C | △ = 20 C | ▼ = 14 C | □ = 11 C night | ★ = several points |
| ● = 32 C | △ = 26 C | ▼ = 20 C | □ = 17 C day | |
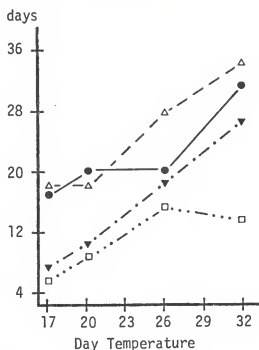
Fig. 23. Height of mainstem by day temperature.
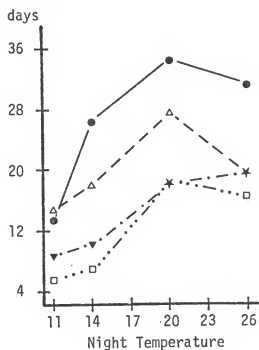
Fig. 24. Height of mainstem by night temperature.
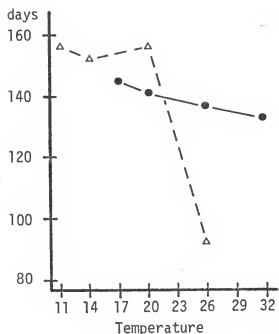
Fig. 25. Total length of development through the flowering period by day or night temperature group.
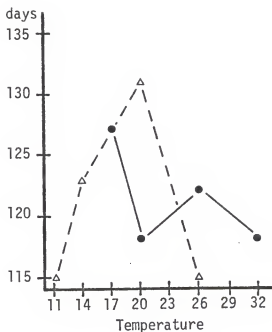
Fig. 26. Length of filling period by day or night temperature group.

● = day temperature;   △ = night temperature;   ★ = several points
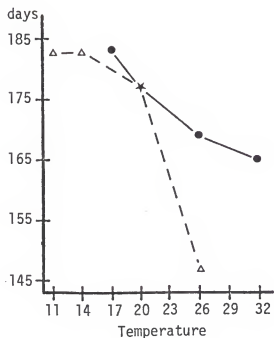
Fig. 27. Total length of development through final harvest by day or night temperature group.
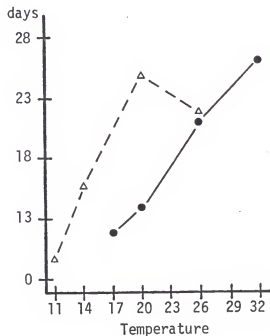
Fig. 28. Height of mainstem by day or night temperature group.

Again, the temperature interaction found in the flowering period figures (Figs. 15, 16, 17, and 18) is present in Figs. 19 and 20. The treatment trend-lines in Figs. 19 and 20 cross each other instead of following similar patterns. The interaction occurred despite the variability of the harvest dates. Part of the cause is undoubtably the termination procedures where the coolest treatments were harvested first because their estimated harvest dates preceded those of higher temperature treatments (discussed earlier). Another probable cause is that this period also includes the flowering period. Day temperature has a similar effect on the two cooler night temperatures of Fig. 19. The effect is also similar between the two warmer night temperatures. Figure 20 shows that night temperature effects the two lower day temperatures similarly and the two warmer day temperatures similarly. The 20/20 and 17/20 treatments show high values since they were some of the last treatments to be harvested.

No clear relation exists for day temperature (r=-.13, P=.6300), for night temperature (r=.00, P=.9899), or for mean temperature (r=-.06, P=.8389) as indicated by correlation coefficients (Fig. 26). The low coefficients are undoubtably a partial result of the variability in the final harvest dates of the treatments. The sharp decrease from the 20 to the 26 C night temperature is of interest. This drop indicates that a higher night temperature substantially decreased the length of the filling period. A large pod load in the 26 C night temperature treatments apparently ended flowering early in these treatments. The early end to the flowering accounts for much of the decrease in period length. The shorter flowering

period combined with a theoretically faster pod fill (in relation to both growth and development) would result in shorter filling periods. Many treatments did not obtain full pod loading. The unique relation of the cooler treatments ending bloom in similar lengths of time as the warmer treatments (as discussed in the "Flowering Period Length" section) probably caused the lack of correlation to day, night, or mean temperature. The variability of final harvest dates (discussed earlier) was probably a factor also.

The large amount of literature (discussed in the Review of Literature) describing various effects of temperature on flowering, peg formation, pod formation, seed weight, and pod number indicates that temperature should have an effect on the filling period's length. Of interest, though, is the findings of Davis (1968) that various planting dates all tended to mature at the same time and the conclusion of Dr. J. H. Williams (personal communication; Crop Breeding Institute, Salisbury, Rhodesia) that the peanut can vary the development of established fruits to the photosynthate supply. The latter findings could account for some of the lack of temperature correlation to the length of the filling period.

The correlation of filling days to the total days of development through filling shows a large reduction from the correlation of flowering period length to the total days of development through flowering. The r-value is .72 (P=.0015). While it is still quite significant, the lower r-value indicates a continued decrease in r-value from the high correlation found at the end of the vegetative period. The factors that caused a lack of temperature correlation to the filling period length undoubtably were a major effect on the lower correlation.

As was done in the flowering period analysis, the temperature treatments were divided into two groups. The first group was of treatments with mean temperatures of 20 C or higher and the second group was of treatments with means of 19 C or lower. Like the flowering period, the data division produced significance for mean temperature. For the group of treatments with means of 20 C or higher, the correlations for mean, day, and night temperatures are $r=-.84$ (P=.0089), $r=-.49$ (P=.2213), and $r=-.45$ (P=.2610), respectively. The correlations for the 19 C or lower group are $r=.89$ (P=.0028), $r=.76$ (P=.0271), and $r=.16$ (P=.7082), respectively. Day temperature for the latter group is significant at the 3% level. The day temperature significance is in contrast to the significance for day temperature in the flowering period analysis.

The data division greatly increased the correlation of the filling period length to the total days of growth and development through filling. The correlations are $r=.95$ (P=.0003) and $r=.95$ (P=.0003) for the 20 C or higher group and 19 C or lower group, respectively.

As occurred in the flowering period, the division of the treatments increased the correlations of the filling period length. Since the filling period length also contained the length of the flowering period, the similar data division effect on both periods is expected.

Length of the Total Growth Period

The interaction of treatment effects seen in Figs. 17 and 18 for the length of development through flowering is also present in Figs. 21 and 22. Figure 21 shows a strong similarity to Fig. 17. But the range in days of growth in Fig. 21 is two-thirds that

of Fig. 17. The treatment interaction in Fig. 22 is smaller than
that seen in Fig. 18.

As discussed earlier, the low correlation of filling period
length to the total growth period length was probably partially caused by the
low correlation of filling period length to temperature. The total
growth period length also shows a lack of correlation to mean
temperature, day temperature, and night temperature (Fig. 27).
The r-values are -.70 (P=.0023), -.32 (P=.2314), and -.63 (P=.0090),
respectively. Although the mean temperature and night temperature
r-values are highly significant, they are somewhat low. The three
correlations did show a slight r-value increase from the r-values
of the total length of development through flowering.

The division of the treatments into two groups gave correlations
of r=-.93 (P=.0007), r=-.24 (P=.5610), and r=-.70 (P=.0518) for
mean, day, and night temperatures, respectively, for the 20 C or
higher mean temperature group. The correlations are r=.80 (P=.0178),
r=.02 (P=.9598), and r=.79 (P=.0198), respectively, for the 19 C
or lower mean temperature group. The r-values for the mean temper-
ature correlation of the 20 C or higher mean group and the day
temperature correlation of the 19 C or lower group are the only
marked changes that occurred from the correlations obtained for all
treatments. The division of the treatments did not greatly enhance
the correlation coefficients and their probable levels. The lack
of enhancement may be a result of the variability in final harvest
dates discussed earlier.

Williams (1975) found that warmer temperatures increased the
rate of phenological development, but his coolest temperatures did

Table 11. Height of the mainstem of average treatment plants.

Treatment	Mainstem Height (cm)	Treatment	Mainstem Height (cm)
32/26	31.8	20/26	19.5
32/20	34.3	20/20	18.5
32/14	25.6	20/14	10.7
32/11	13.3	20/11	8.0
26/26	20.8	17/26	16.3
26/20	28.4	17/20	17.9
26/14	19.0	17/14	6.8
26/11	14.7	17/11	5.5

not have longer growth periods since growth factors modified the lengthening effect of the cooler temperatures. Williams' findings coincide well with my research. Growth factors apparently controlled the length of the cooler treatments' development periods. Dreyer (1980) found that increasing fruiting zone temperatures produced a trend towards earlier or more mature fruits per plant.

Mainstem Height

Although only one height measurement was taken per treatment, correlations were produced to show the relationship to day, night, and mean temperatures. Since variation undoubtably existed in mainstem height among plants of the same treatment, the results of the correlations cannot be considered to have high accuracy. Nevertheless, the measurements and correlations exhibit the trend of temperature effect on mainstem height. The plant photographs discussed in the following section show the differences in plant growth habit created by the differences in mainstem height (Table 11).

An r-value of .82 (P=.0001) was found for a correlation with mean temperature while a day temperature correlation produced an r-value of .69 (P=.0033) and a night temperature gave .57 (P=.0201). Night temperature is not significant at the 1% level. The somewhat low night temperature correlation is probably accounted for by the break in the trendline between the 20 and 26 C night temperature groups (Figs. 24 and 28). The 26 C night temperature plants were somewhat more prostrate (Figs. 29 to 35). Day temperature is significant but not to the extent that mean temperature is. The day temperature line in Fig. 28 is almost linear but a look at Fig. 23 shows that there is variation (interaction) in the effect of day temperature on each night temperature. Figure 24 shows that the 20 C night temperature is effective in increasing the height of the mainstem and therefore bushiness of the plant of the two warmer day temperatures. All night temperatures, but the coolest, had increased mainstem height at 32 C day temperature (Fig. 23).

Plant Photographs

The following section contains forty photographs of treatment plants. These photographs will be valuable for reference during the following discussions on the results of various analyses. Figures 29 to 32 show representative plants of the sixteen temperature treatments. Each photograph shows the four night temperature plants of each day temperature. Figures 33 to 36 show the same representative plants as in the previous photographs, but the plants are arranged to show the four day temperature plants of each night temperature. The arrangement of Figs. 29 to 36 allows for visual comparison of the plants as affected by night temperature within day temperature and by day temperature within night temperature.

The plants of the final harvest are presented in Figs. 37 through 52. In three cases (32/11, 20/20, and 17/20) only four of the seven or eight plants harvested are shown. These plots allow for visual comparison of plant growth habits and size between treatments and of plant uniformity within each treatment. The centimeter scale in the center background of each photo allows for estimation of the size of each plant. Although the photos are taken at a downward angle to the plants, the scale also allows for comparison of the height of the mainstem and other branches. The zero of the scale was set at the height of the pot and the podding-box tops. Each page of four photographs is arranged with one day temperature with the corresponding four night temperatures in descending order.

Representative, depotted and invested plants of each treatment are shown in Figs. 53 through 68. Again, these pictures are arranged with one day temperature and four night temperatures (in descending order) on each page of figures. These photos are extremely useful for visual comparison between treatments of pod load, root size, leaf size, stem size, and plant size. The use of the center-situated centimeter scale allows for size comparisons. A comparison of the ratios of roots, stems, leaves, and pods to each other within each treatment is also possible.

Plant Component Analyses

The data points on all figures for the various measurements are mean values. In the case where all treatments are presented, the means are for three to eight plants. The figures presenting

Fig. 29. Photograph of representative plants at 32 C day temperature and 26, 20, 14, and 11 C night temperatures on day 135 of experiment.

Fig. 30. Photograph of representative plants at 26 C day temperature and 26, 20, 14, and 11 C night temperatures on day 135 of experiment.

Fig. 31. Photograph of representative plants at 20 C day temperature and 26, 20, 14, and 11 C night temperatures on day 135 of experiment.

Fig. 32. Photograph of representative plants at 17 C day temperature and 26, 20, 14, and 11 C night temperatures on day 135 of experiment.

Fig. 33. Photograph of representative plants
at 26 C night temperature and 32, 26, 20,
17 C day temperatures on day 135 of
experiment.

Fig. 34. Photograph of representative plants
at 20 C night temperature and 32, 26, 20,
17 C day temperatures on day 135 of
experiment.

Fig. 35. Photograph of representative plants
at 14 C night temperature and 32, 26, 20,
17 C day temperatures on day 135 of
experiment.

Fig. 36. Photograph of representative plants
at 11 C night temperature and 32, 26, 20,
17 C day temperatures on day 135 of
experiment.

Fig. 37. Photograph of treatment 32/26 potted plants at final harvest.

Fig. 38. Photograph of treatment 32/20 potted plants at final harvest.

Fig. 39. Photograph of treatment 32/14 potted plants at final harvest.

Fig. 40. Photograph of treatment 32/11 potted plants at final harvest.

Fig. 41. Photograph of treatment 26/26 potted plants at final harvest.

Fig. 42. Photograph of treatment 26/20 potted plants at final harvest.

Fig. 43. Photograph of treatment 26/14 potted plants at final harvest.

Fig. 44. Photograph of treatment 26/11 potted plants at final harvest.

Fig. 45. Photograph of treatment 20/26
        potted plants at final harvest.

Fig. 46. Photograph of treatment 20/20
        potted plants at final harvest.

Fig. 47. Photograph of treatment 20/14
        potted plants at final harvest.

Fig. 48. Photograph of treatment 20/11
        potted plants at final harvest.

Fig. 49. Photograph of treatment 17/26 potted plants at final harvest.

Fig. 50. Photograph of treatment 17/20 potted plants at final harvest.

Fig. 51. Photograph of treatment 17/14 potted plants at final harvest.

Fig. 52. Photograph of treatment 17/11 potted plants at final harvest.

Fig. 53. Photograph of a representative, depotted, inverted plants of treatment 32/26 at final harvest.

Fig. 54. Photograph of several representative, depotted, inverted plants of treatment 32/20 at final harvest.

Fig. 55. Photograph of several representative, depotted, inverted plants of treatment 32/14 at final harvest.

Fig. 56. Photograph of several representative, depotted, inverted plants of treatment 32/11 at final harvest.

32-20 DAY 145
MARVEST 3 12-5-76

32-11 DAY 187
MARVEST 3 1-16-77

32-26 DAY 138
MARVEST 3 11-26-76

32-14 DAY 188
MARVEST 3 1-17-77

Fig. 57. Photograph of several representative, depotted, inverted plants of treatment 26/26 at final harvest.

Fig. 58. Photograph of several representative, depotted, inverted plants of treatment 26/20 at final harvest.

Fig. 59. Photograph of several representative, depotted, inverted plants of treatment 26/14 at final harvest.

Fig. 60. Photograph of several representative, depotted, inverted plants of treatment 26/11 at final harvest.

28-28   DAY 160
HARVEST 3 12-30-76

28-11   DAY 187
HARVEST 3 1-16-77

28-28   DAY 135
HARVEST 3 11-30-76

28-14   DAY 191
HARVEST 3 1-20-77

Fig. 61. Photograph of several representative, depotted, inverted plants of treatment 20/26 at final harvest.

Fig. 62. Photograph of several representative, depotted, inverted plants of treatment 20/20 at final harvest.

Fig. 63. Photograph of depotted, inverted plants of treatment 20/14 at final harvest.

Fig. 64. Photograph of depotted, inverted plants of treatment 20/11 at final harvest.

20 - 20 DAY 187
HARVEST 3

20 - 28 DAY 154
HARVEST 3

20 - 11 DAY 186
HARVEST 3

20 - 14 DAY 186
HARVEST 3
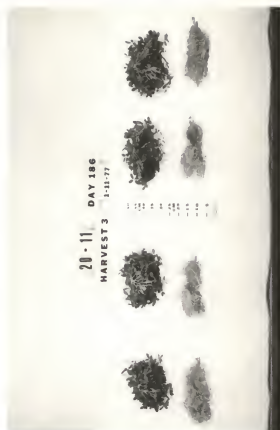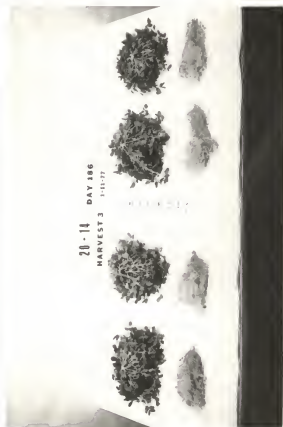
Fig. 65. Photograph of several representative, depotted, inverted plants of treatment 17/26 at final harvest.

Fig. 66. Photograph of several representative, depotted, inverted plants of treatment 17/20 at final harvest.

Fig. 67. Photograph of depotted, inverted plants of treatment 17/14 at final harvest.

Fig. 68. Photograph of depotted, inverted plants of treatment 17/11 at final harvest.

17-20   DAY 216   HARVEST 3   2-14-77

17-20   DAY 163   HARVEST 3   12-21-76

17-11   DAY 175   HARVEST 3   1-4-77

17-14   DAY 175   HARVEST 3   1-4-77

mean points for each day or night temperature group are means of
fourteen to twenty-four plants. The means are presented by both day
and night temperature for the figures showing all sixteen treatments.
The latter format allows for comparison of the night and day tempera-
ture effects as do the figures showing means of the night and day
temperature groups. The lines connecting data points should not
be taken as estimations of the response curves between treatments.
The lines are only present to allow quick visual understanding of
the graphs. The numerical values for all figures are listed in
Appendix tables.

Total Dry Weight

Analysis of variance is highly significant (Appendix Tables
E-1 and E-2) for day and night temperature and day-night temperature
interaction. The R^2 value is .98 at the final harvest indicating
that almost all non-experimental variation was removed from the
experiment for this variable. The night temperature F-value is
approximately forty times greater than the day temperature value.
The large night temperature F-value indicates a greater effect of
night temperature on the total dry weight of the plant. However,
the amount of increased night temperature effect attributable to
the longer duration of night temperature is unknown.

Analysis of variance R^2 values and significances for separate
night and day temperatures are all high with few exceptions (Appendix
Tables C-1, C-2, C-3, and C-4). A day temperature of 32 C has a
slight reduction in R^2 value for the second harvest. The 32 C value
increases to a high level by the final harvest. The 26 C night

temperature group has a low R^2 value in the final harvest and is non-significant at the 5% level. The reduced significance is attributable to the similarity of the dry weight among the four day temperatures of the 26 C night group.

Treatment 17/20 had the highest dry weight in both harvests and was significantly higher than all other treatments (Figs. 69, 70, 71, and 72). The coefficient of variability was less than 15% for almost all treatments while many values were less than 5% (Appendix Table B-1). All treatments showed the same graphic relationship between the two harvests. The 26 C night temperature plants, however, increased in weight more than the other night temperatures (Appendix Tables A-1 and A-2).

There was a marked change between the two harvests (Figs. 73 and 74) for means of day and night temperature groups. The 26 C night plants had a major weight increase while the three higher day temperatures increased weight slightly in the final harvest (Tables D-1 and D-3). Although the 17/20 treatments produced the highest total dry weight the 20/20 treatment was also quite high (Tables A-1 and A-2). Both treatments had large amounts of vegetative material with little reproductive weight. The latter was cause for the 20 C night temperature exhibiting such a high mean value (Figs. 73 and 74). The 26 C night temperature mean increased sharply due to the large production of reproductive dry weight in the 26 C night treatments.

De Beer (1963) found that as temperature increases, so does dry weight. Figures 73 and 74 indicate De Beer's statement to be valid for night temperature means but not for day. Figures 69, 70,

71, and 72 show that his statement is valid only for night temperatures up to 26 C regardless of day temperature. Williams (1975) also found higher temperatures to increase the amount of plant growth. The above discussion is also applicable to his findings. Fortanier (1957) and Bolhuis and De Groot (1959) showed that yield is related to total growth. In comparing total dry weight or total vegetative weight with total pod yield, this is definitely not the case in my research. Williams' (1975) finding that vigorous growth limited yield potential is more in concurrence with my experiment. Increase in dry weight with increasing day temperature is only present when the night temperature is cooler (Figs. 69 and 71). Variability between treatment dry weight is high in Figs. 69 and 71 (Tables A-1 and A-2).

Both the cooler day and night temperature groups have an apparent critical "break-point" between 20 and 26 C day and 14 and 20 C night temperature. This break is only present at the lower day or night temperatures. The critical "break-pcint" will be seen in much of the other data studied. The "break-point" caused a crossover (temperature interaction) of data points in the figures by night temperature (Figs. 70 and 72). Figure 69 shows a slight amount of interaction in data points.

Fortanier (1957) concluded that when the average temperature is the same, the dry weight is greatest in treatments with the lowest temperature difference or the lowest night temperature. Comparing total dry weight with mean temperatures in my experiment, the findings of Fortanier do not agree with my research. Fortanier concluded that dry weight is dependent first on average temperature with distribution of temperature over night and day being less
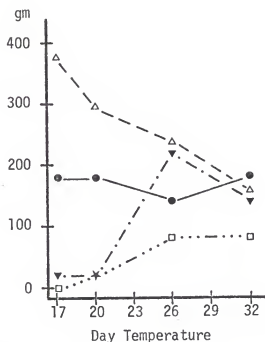
Fig. 69. Total dry weight for the second harvest by day temperature.
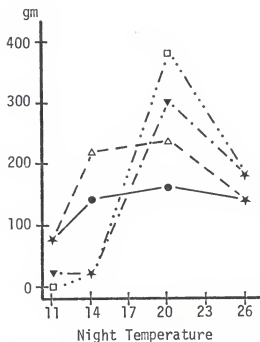
Fig. 70. Total dry weight for the second harvest by night temperature.

● = 26 C	△ = 20 C	▼ = 14 C	□ = 11 C night	★ = several points
● = 32 C	△ = 26 C	▼ = 20 C	□ = 17 C day	
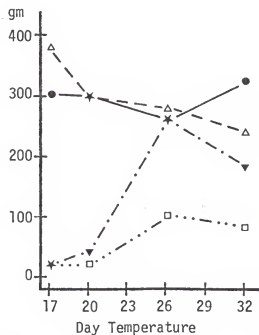
Fig. 71. Total dry weight for the final harvest by day temperature.
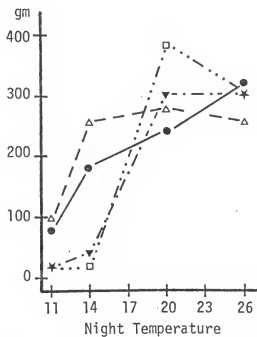
Fig. 72. Total dry weight for the final harvest by night temperature.
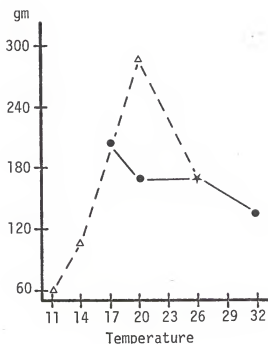
Fig. 73. Total dry weight by day or night temperature group for the second harvest.
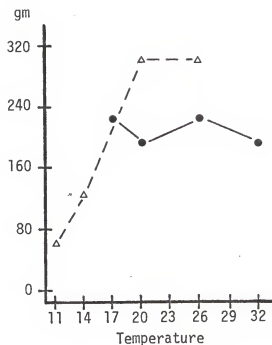
Fig. 74. Total dry weight by day or night temperature group for the final harvest.

● = day temperature; △ = night temperature; ★ = several points
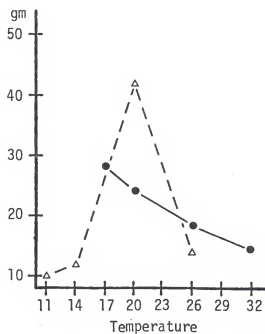
Fig. 75. Root dry weight by day or night temperature group for the second harvest.
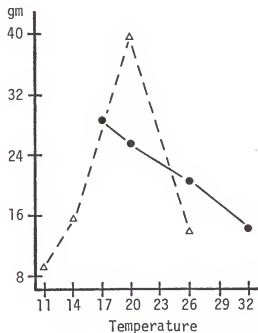
Fig. 76. Root dry weight by day or night temperature group for the final harvest.

important if the difference is not greater than 20 C. Again, agreement cannot be found with the research presented here.

Simmons and Brown (1972), in work on photosynthesis, found temperature to affect photosynthetic rates and the intensity of light at which light saturation occurs in single peanut leaves. Twice as many foot-candles were photosynthetically active at 20 C than at 10 C. At a specific light intensity, maximum photosynthesis was found at 30 C while the photosynthetic level was 70% of maximum at 20 C and 10% of maximum at 10 C. The coolest day temperature in my research was 17 C. The latter findings may partially explain why day temperature had a lower F-value for total dry weight than did night temperature (Appendix Tables E-1 and E-2).

The cause of linear downward trend of dry weight with increasing day temperature at a night temperature of 26 C (Figs. 69 and 71) can possibly be explained by inactivation at the cooler day temperatures of the enzyme controlling phospho-glycolate production. This loss of phospho-glycolate could significantly reduce photorespiration and should increase dry matter production. Went (1953) found that the photosynthesis to respiration ratio is larger at lower temperatures. He believes the latter possibly explains why many plants produce more vigorous growth in temperature regions than in the tropics. In conflict with Went is the finding by Moss et al. (1961) that although respiration increases at a faster rate than photosynthesis at higher temperatures in corn, photosynthesis is so much larger in value that the net assimilation increases. It should be remembered, though, that corn is a C_4 plant.

Fortanier (1957) found 32 C day temperature to be optimum for growth at night temperatures of 32 and 23 C. Very little growth was found at 20/20 and 15/20. His data does not fully agree with my research. While the 32/26 treatment did have a high total dry weight, the 17/20 treatment had the highest. Fortanier also states that while it is generally accepted that night temperature should be low to reduce respiration and therefore increase dry weight production, he did not find support for this idea in his research. The dry weights in Fortanier's plants were actually higher at the higher night temperatures. The research presented here supports Fortanier's findings. High night temperatures actually proved favorable.

Dreyer (1980) found that fruiting zone temperatures did not affect the total plant dry weight. The lack of temperature effect in Dreyer's study indicates that all differences found in my study were caused by the air temperature effect on plant tops and not on the temperature within the pots. This conclusion is somewhat questionable, though, since roots were affected greatly by temperature and the lack of pod production in some treatments appeared to greatly increase vegetative dry weight of those treatments (notably the 17/20 and 20/20 treatments).

Only two treatments in the experiment had continuous temperatures for the full twenty-four hours. These were the 20/20 and 26/26 treatments. Total dry weight shows a slight depression for the 26/26 treatment. This depression becomes more marked for other measurements and possibly indicates a thermoperiodic effect of the Florunner variety of peanut. While most authors (as discussed in

the Review of Literature) feel that the peanut exhibits no thermo-
periodic effect, the conclusion from my research is that it does.
Although the 20/20 treatment had a marked increase in dry weight,
it was a transition treatment between those that produced pods and
those treatments that did not. Therefore, any overall thermo-
periodic effect could have been easily masked.

Root Dry Weight

By far the highest root weights were obtained in the 17/20
and 20/20 treatments (Figs. 77, 78, 79, and 80; Tables A-3, A-4,
and B-1). More relative difference in weight is present in this
variable than there was in total dry weight. Both the highest
day and night temperatures show little variation though significance
is present. Thermoperiodicity does not appear in these data. Very
little difference is present between second and final harvest data.
It appears most root growth had occurred by the second harvest with
most change in total dry weight between harvests being accounted
for by other factors. The largest shift between the two harvests
occurred with the 32/14 treatment. A slight temperature interaction
crossover effect is present as it was in total dry weight. The two
cooler day and night temperatures show an apparent critical
"break-point" between 20 and 26 day and 14 and 20 C night tempera-
tures. Treatments with lower temperatures show depressed values.
The "break-point" disappeared with the higher temperatures. The
20 C night plants (Figs. 77 and 79) have a unique graphical relation,
possibly caused by the 17/20 and 20/20 treatments.

The C.V.s (Appendix Table B-1) for the treatments are similar to that for total dry weight with the treatments that produced more dry matter exhibiting the lowest C.V. It is possible that more of the fine, sparsely growing roots were lost in the harvest process of the cooler treatments than were lost for the bulkier, matted growth of the warmer treatments. However, the C.V.s would normally be lower in treatments with greater dry weights.

F-values for day and night temperature and day-night temperature interaction are all highly significant (Tables E-1 and E-2). As with total dry weight, there is a tenfold increase in F-value for night temperature over the day temperature F-value. While the significance is extremely high, the F-value increase indicates a possible greater importance of night temperature. The amount of the increase attributable to the night temperature treatment period being twice as long as that of day temperature is unknown.

There is basically no change between harvests for temperature group means (Figs. 75 and 76; Tables D-1 and D-3). A downward, linear trend is seen for day temperature while night temperature-- excluding the 26 C treatment--is the opposite. The marked drop of the 26 C night plants is of major interest. The four treatments of the 26 C night temperature regime all produced very large plants with high yields of fruit. A night temperature regime of 20 C gave an almost fourfold increase over that seen for 26 C. Both the 17/20 and 20/20 treatments are in this group and they had by far the greatest root growth. The 17/20 and 20/20 treatments had little pod growth while the temperatures apparently were warm enough to produce a large amount of vegetative dry matter.

Fig. 77. Root dry weight for the second harvest by day temperature.

Fig. 78. Root dry weight for the second harvest by night temperature.

| ● = 26 C | △ = 20 C | ▼ = 14 C | □ = 11 C night | ★ = several points |
| ● = 32 C | △ = 26 C | ▼ = 20 C | □ = 17 C day | |
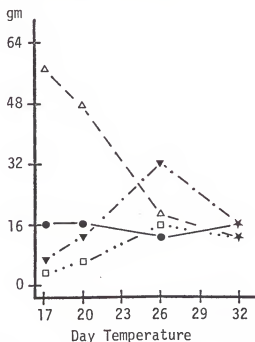
Fig. 79. Root dry weight for the final harvest by day temperature.
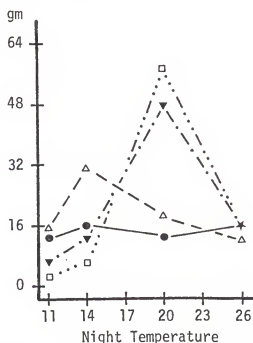
Fig. 80. Root dry weight for the final harvest by night temperature.

Analysis of variance R^2 values and significances for separate day and night temperature groups (Appendix Tables C-1, C-2, C-3, and C-4) are all high with the exception of the 32 C day temperature and 26 C night temperature groups. The R^2 value of the 32 C day group is low at the second harvest and decreases at the final harvest. While the night temperatures within this group have significance lower than the 1% level at the second harvest, the significance level is 2% at the final harvest. The 26 C night temperature group R^2 value is low at the second harvest but the significance is high. By the final harvest the R^2 value has decreased and the group significance level is 2%. Apparently a high day or night temperature compensates for a corresponding low day or night temperature. The compensation supports similar findings by Fortanier (1957).

Overall, cooler temperatures are detrimental to root growth. In the case of the cool day temperatures, more roots are apparently needed to support the same amount of top growth while in the night temperatures, the roots are retarded in growth along with the rest of the plant.

Dreyer (1980) found no influence of temperature on root growth. My data show a major influence. Dreyer's treatments, though, only extended for a few centimeters around the podding zone. The small treatment area of Dreyer's study and the difficulty in harvesting large amounts of field grown roots with consistency probably accounts for the difference in these two experiments.

Wood (1968) found some of his most striking data for root dry weights. He concluded that varying night temperatures had little effect; but within the day temperature range of 20-35 C, root growth increased as temperature increased. The latter finding strongly contradicts the findings in this research. In work with three experimental conditions, Gautreau (1973) found his warmer treatments to produce higher root weights. No direct comparison with his research can be made.

Root Dry Weight Percentage

As with root dry weight, the root dry weight percentage changes little between the first and second harvests (Figs. 81, 82, 83, and 84; Tables A-5 and A-6). A few treatments increased percentage while a few decreased slightly. The decreases mostly occurred in the warmer treatments (especially the 26 C night treatment) where continued pod fill after the second harvest would account for the decrease. The small change in percentages indicates that little change occurred in the ratio of the vegetative components to one another. The decrease due to continued pod fill indicates that continued vegetative growth occurred slowly if at all during the inter-harvesting period. The latter is expected as a number of treatments had their final harvests only a short time after the second harvest. And the treatments with heavy pod loads would not be expected to produce vegetative growth. The photosynthate in the heavy pod load treatments is being used to fill pods.

Unlike root dry weight, this variable does not show a tempera- ture interaction crossover effect caused by a "break-point." Nevertheless, the break-point still exists between the temperatures

mentioned earlier for the cooler day or night temperatures. There
is little or no significance shown between the 26 C night temperature
plants (Appendix Tables C-2 and C-4). The low significance indicates that,
at warm night temperatures, day temperatures had no effect on the
ratio of root to total dry weight (Tables A-5 and A-6). The
warmer day temperatures show reduced slopes but still exhibit
significant differences between treatments (Figs. 81 and 83;
Tables C-1 and C-3).

All day or night temperatures have decreasing percentages as
temperature increases (Tables A-5 and A-6). There is also decreasing
variance between the four treatments within each day or night tem-
perature as temperature increases.

Day and night temperature and day-night temperature interaction
are all highly significant with high R^2 values (Appendix Tables E-1
and E-2). The respective F-values are more similar than for previous
variables. Day and night temperatures appear to share equally in
the effect on this variable. Tables D-1 and D-3 present the mean
values and Duncan's MRT for the above figures. Percentages decrease
as day or night temperature increases in Figs. 85 and 86. Both
graphs are similar except for the sharp "break-point" seen for day
temperature in Fig. 85. This break disappears by final harvest.
The reason is unknown.

The treatment C.V.s are lower than the C.V.s for root and total
dry weights (Appendix Table B-2). Most are below 10%. The coolest
treatments had significantly greater percentages of dry weight as
roots with the higher pod yielding treatments having the smallest
percentages.
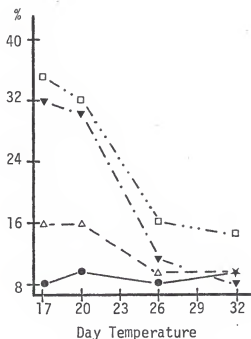
Fig. 81. Root dry weight percentage for the second harvest by day temperature.
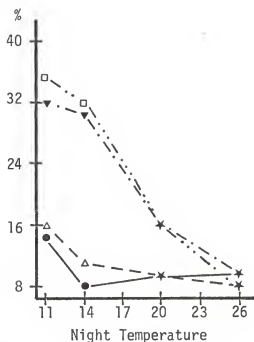
Fig. 82. Root dry weight percentage for the second harvest by night temperature.

● = 26 C	△ = 20 C	▼ = 14 C	□ = 11 C night	★ = several points
● = 32 C	△ = 26 C	▼ = 20 C	□ = 17 C day	
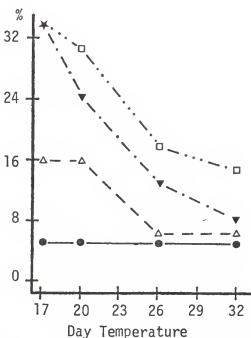
Fig. 83. Root dry weight percentage for the final harvest by day temperature.
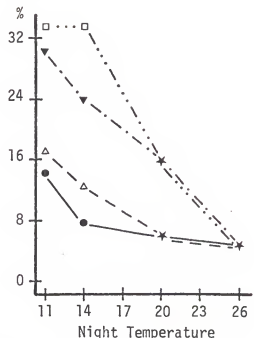
Fig. 84. Root dry weight percentage for the final harvest by night temperature.
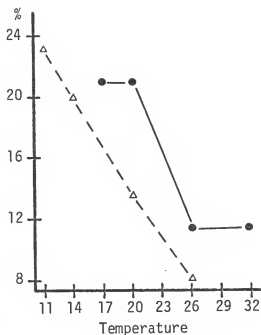
Fig. 85. Root dry weight percentage by day or night temperature group for the second harvest.
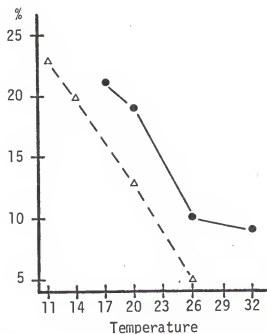
Fig. 86. Root dry weight percentage by day or night temperature group for the final harvest.

● = day temperature;   △ = night temperature;   ★ = several points
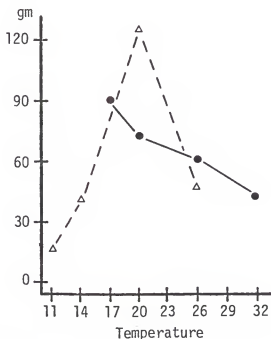
Fig. 87. Stem dry weight by day or night temperature group for the second harvest.
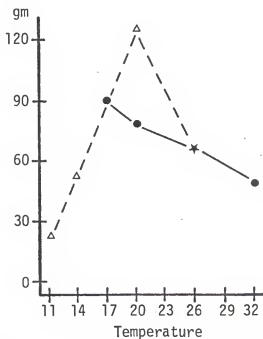
Fig. 88. Stem dry weight by day or night temperature group for the final harvest.

The higher percentages for the cooler day temperatures indicate a need for greater root growth at these temperatures in order to supply the plant with needed nutrients. It is also possible that solar radiation on pots of the cooler treatments increased substrate temperature above ambient air temperature thereby allowing increased root growth. Increase in substrate temperature would occur in these treatments as the plants had not fully covered the surface area of the pots (see photographs). The warmer treatments did cover the pot surface area. The latter would not explain the night temperature effect.

Van Dobben (1962) is the only author found to have made shoot-root ratio observations with respect to temperature. His work with wheat indicated that the ratio increases at higher temperatures without reaching an optimum within the range of his investigations. His results are the same as my research. No maximums were found in my experiment except with the possible exception of the 26 C plants.

Stem Dry Weight

The stem dry weight figures (Figs. 89, 90, 91, and 92) resemble those of root dry weight and total dry weight. The similarity with the latter two variables indicates that the differences seen in root dry weight percentages between harvests were caused by differences in total pod dry weight.

The second and final harvest graphs are similar in the relative positioning of the treatments. A number of treatments, though, increased weight (Appendix Tables A-7 and A-8). One treatment lost weight, probably due to sampling error. The same temperature "break-points" and interaction (line crossover) as discussed for root dry

weight exist for stem dry weight. The discussion of the "break-points" and interaction in the root dry weight section is applicable to stem dry weight.

The 20 C night temperature plants show a unique relation due to the 17/20 and 20/20 treatments. The largest increases in weight occurred in the 26 C night plants with 17/26 gaining almost 30 gm dry weight. Of interest is the large increase in stem dry weight of the 26/14 treatment. A slight increase in the root dry weight of the 26/14 treatment occurred but not to the same extent as the stem increase. Total dry weight for this treatment only slightly reflects this increase. The reason is unknown. It is possible that this treatment experienced the same photosynthate partitioning as occurred in the 17/20 and 20/20 plants. The 32/14 treatment yielded a number of pods while the 26/14 treatment produced very few. The 32/14 treatment did not have a large increase in stem weight.

The R^2 values in Appendix Tables C-1 through C-4 are high for day temperature except for a slight decrease for the second harvest's 32 C temperature. A more substantial drop is present in the 26 C night temperature group. The second harvest has minimal significance at the 5% level for the 26 C group. The final harvest shows a smaller drop. The lower R^2 values for the 26 C night group indicates that a high night temperature counteracts day temperature effects. The latter is in agreement with Fortanier's (1957) statement that a high day or night temperature can counteract the effect of a low night or day temperature. The C.V.s for this variable appear slightly higher than those for total dry weight but lower than those for root dry weight (Appendix Table B-2).

As day temperature increases, the variation between the four night treatments within each day temperature decreases. For night temperatures, the center two temperature groups show the largest variation while the groups at both ends present less (Figs. 86 and 88).

Analysis of variance yielded high R^2 values and high significance for day and night temperature and day-night temperature interaction (Appendix Tables E-1 and E-2). The much higher F-value for night temperature indicates that night temperature may exert more influence on stem dry weight than day temperature. The day and night temperature groups in Figs. 87 and 88 exhibit the same basic trends for both harvests (Tables D-1 and D-2). The high value for the 20 C night temperature group is due (as it was with root dry weight) to the 17/20 and 20/20 treatments. Stem weight slowly decreased with increasing day temperature; a fact that is in contrast to authors cited in the section on total dry weight. The sharp drop of the 26 C night temperature mean is probably caused by this temperature's treatment not exhibiting the negative effects of the cooler day temperatures on peg and pod production. The lower stem weight of the 26 C night group may be explained by Duncan's (1976) suggestion that top growth ceases as soon as there are enough peanuts to use all the photosynthate being produced. He states that the sooner this occurs, the less top growth there should be. Rapid pod formation and a full pod load (in some cases) is probably why the warmer day temperatures showed less stem growth.

The lower stem growth in the cool night temperatures undoubtably is caused by a direct effect of temperature on development and growth processes in the plant top; but, the effect of temperature on root
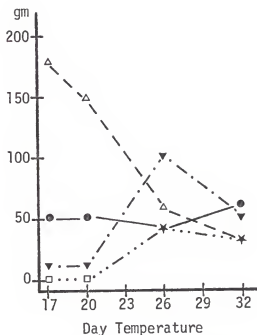
Fig. 89. Stem dry weight for the second harvest by day temperature.
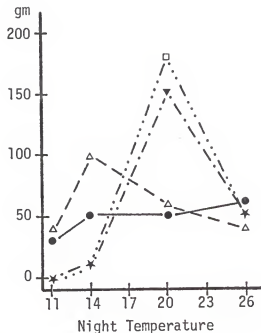
Fig. 90. Stem dry weight for the second harvest by night temperature.

| ● = 26 C | △ = 20 C | ▼ = 14 C | □ = 11 C night | ★ = several points |
| ● = 32 C | △ = 26 C | ▼ = 20 C | □ = 17 C day | |
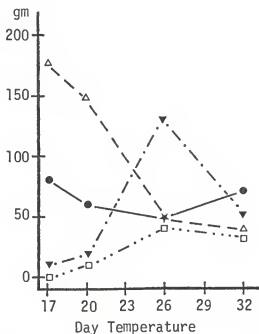
Fig. 91. Stem dry weight for the final harvest by day temperature.
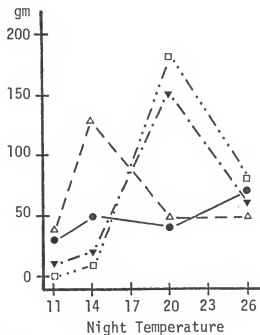
Fig. 92. Stem dry weight for the final harvest by night temperature.

growth can have an indirect effect upon stem growth. Sellschop and Salmon (1928) found chilling peanut seedlings at .5 to 5 C to not immediately affect top growth but to damage the root system enough to stunt growth or cause plant death.

My research contradicts the findings of De Beer (1963), Fortanier (1957), Khalil (1956), Williams (1975), and Wood (1968) who found stem weight to increase at higher temperatures. My study shows that the effect of increasing temperatures depends largely on day-night temperature interaction. Fortanier (1957) found growth in peanuts to be greater when night temperature was higher than day. In my experiment, one treatment, 17/20, had a day temperature lower than the night in the 20 C night regime. This treatment, as stated before, had unusual growth patterns and produced the highest total dry weight. This pattern may have been affected by the higher night temperatures. Two of the 26 C night temperature treatments also exhibited the unusual benefit of the higher night-cooler day temperature growth regime. The 20/26 treatment produced the highest yield while the 17/26 plants produced the largest number of pods. The stem dry weight and total dry weight did not show an increase in the 26 C night temperature treatments with cooler day temperatures.

Stem Dry Weight Percentage

The stem dry weight percentage graphs (Figs. 93, 94, 95, and 96) show little relation to the root dry weight percentage graphs. Both harvests are graphically similar but there are some major shifts present. Most of the 26 C night plants dropped in percentage for the third harvest while the two higher day temperatures at 20 C

night dropped markedly (Appendix Tables A-7 and A-8). Undoubtably, most of the cause of this drop is attributable to the fact that these six treatments produced the greatest pod growth. Why root dry weight did not also have as sharp a drop is not immediately clear. Apparently the roots continued some growth in these treatments. Continued root growth would indicate that while photosynthate transport to the growing points of the aerial parts of the plant slowed after the second harvest, the roots were still growing.

The 17/20 and 20/20 treatments show marked variation from the root dry weight percentage graphs. It appears that while these two treatments resembled the warmer 20 C night temperature plants in total photosynthate and therefore dry matter produced, they were not able to produce pods. The increase in total dry weight for these treatments can be explained by the fact that pods need approximately 1.65 times the photosynthate per unit dry weight as does vegetative material (McGraw, 1977). Therefore, the large increase in stem dry weight and dry weight percentage is because there was no pod fraction present for photosynthate partitioning. In the case of these treatments, the excess photosynthate over that required for canopy maintenance was converted to excess canopy growth.

The higher weights of the 26/14 and 26/11 treatments are probably explainable in a similar manner. The 32/14 and 32/11 treatments produced a few pods while the 26/14 and 26/11 treatments did not.

The stem dry weight percentage data have similar "break-points" and treatment interaction as the stem dry weight data. Only the 20 C night and 26 C day temperatures show the clear "break-points." The interaction of photosynthate supply vs. pod number undoubtably

confounded these graphs. For the second harvest (Appendix Tables C-1 and C-2) 12 and 20 C night temperature groups are highly significant and have high R^2 values. The 11 and 26 C groups have depressed R^2 values with the 26 C group having non-significance between its day temperature treatments. The only night temperature group to have a low R^2 and non-significance (at the 1% level) is 32 C. The final harvest (Tables C-3 and C-4) night temperature groups all have significance but the 11 C group has a reduction in its R^2. There is also a slight drop in R^2 at 26 C night. All day temperatures have high R^2 values and significances.

All F-values in Appendix Tables E-1 and E-2 are highly significant. The R^2 values are quite high indicating removal of most non-experimental variation. In Figs. 97 and 98, the warmer day and night temperature treatment groups drop in percentage between the two harvests. These drops are caused by the percentage decreases seen in the individual treatments. The drop of the 20 C night plants from the second to final harvest involves the decrease seen in the 32/20 and 26/20 plants. The figures do not resemble those for root dry weight percentage. While root percentage showed a basic linear decrease as temperature increased, stem dry weight percentage shows a different relation. Similar values occur for the three lower night temperatures and for the two cooler day temperatures in the final harvest. A linear relation also does not occur for the second harvest. Appendix Tables D-1 and D-2 give the mean values and significances for Figs. 97 and 98.
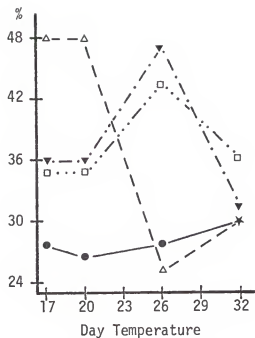
Fig. 93. Stem dry weight percentage for the second harvest by day temperature.

Fig. 94. Stem dry weight percentage for the second harvest by night temperature.

| ● = 26 C | △ = 20 C | ▼ = 14 C | □ = 11 C night | ★ = several points |
| ● = 32 C | △ = 26 C | ▼ = 20 C | □ = 17 C day | |
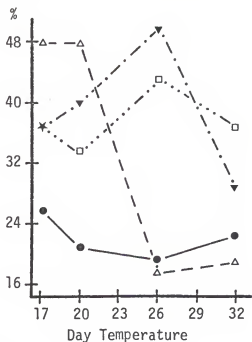
Fig. 95. Stem dry weight percentage for the final harvest by day temperature.
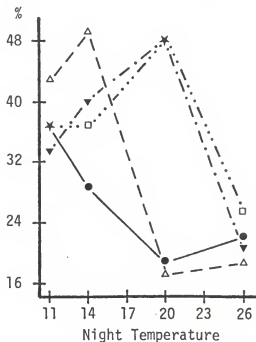
Fig. 96. Stem dry weight percentage for the final harvest by night temperature.

Fig. 97. Stem dry weight percentage by day or night temperature group for the second harvest.

Fig. 98. Stem dry weight percentage by day or night temperature group for the final harvest.

● = day temperature;   △ = night temperature;   ★ = several points

Fig. 99. Leaf dry weight by day or night temperature group for the second harvest.
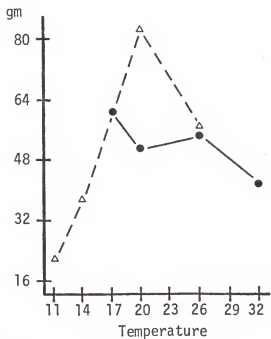
Fig. 100. Leaf dry weight by day or night temperature group for the final harvest.

Leaf Dry Weight

All night temperature group R^2 values are high in Appendix
Tables C-2 and C-4 except for 26 C (non-significant at the 5% level
for the final harvest and 1% level for the second harvest). While
F-values are non-significant, Duncan's MRT (Appendix Table A-12)
does indicate some significance. There is also some slight reduc-
tion at the 20 C night temperature. There are no large reductions
in significance and R^2 values of day temperature groups (Appendix
Tables A-11, C-1, and C-3). In the second harvest the R^2 value
drops slightly at 32 C day but increases by the final harvest.
Fortanier's (1957) statement that a high day or night temperature
can counteract low temperatures is supported in my analyses for
night temperature but not for day. This support is a change from
the effect noticed for stem weight. The C.V. values shown in
Appendix Table B-3 are similar to those seen for previous variables.

The basic graphical relation is the same between both harvests
for all graphs (Figs. 97, 98, 99, and 100). Nevertheless, a weight
increase occurs in many of the final harvest treatments (Table A-11
and A-12). The largest increases occur in the 26 C night tempera-
ture treatments where an increase of up to 20 gm has occurred. Variable
increases occur in the 32 C day treatments, the 11 and 20 C night tem-
peratures show little change while the 14 C night presents a slight
increase. Day temperatures of 17, 20, and 26 C show variable
increases depending upon night temperature. The relatively large
weight increases in all 26 C night plants (especially the 32/26
treatment) do not help to explain the large percentage drops of
stem dry weight percentage discussed earlier. The same relative

increases occurred in stem weight. The reason for the percentage decrease is probably related to the large production of pod dry weight in these treatments.

Percentage increases were sporadic in other treatments. A "flush" of new leaf growth on the lower stem nodes was noticed on several treatments a short time after flowering cessation. A large percentage of this new growth apparently was caused by the generative flower-system at the various nodes becoming vegetative. The latter observation may help explain the increase in leaf weight.

Figures 97, 98, 99, and 100 are graphically similar to the figures of stem dry weight and root dry weight. There are critical temperature "break-points" between 20 and 26 C day temperature and 14 and 20 C night temperature of the two cooler night and day temperature groups. The "break-points" cause a treatment interaction crossover in the figures. Leaf dry weight, as stem dry weight, does not show the thermoperiodic effect believed presented in the 26/26 treatment. The 17/20 and 20/20 plants again have uniquely high dry weights. The 26/14 treatment does not show as large an increase for this variable as was seen in stem dry weight. Leaf dry weight also exhibits the same decreasing variation between treatments as stem dry weight as day temperature becomes warmer and at both 11 and 26 C night temperatures. The low between treatment variation is especially noticeable in the highest day and night temperatures and is the reason for the non-significance discussed earlier. A high R^2 value is present for analysis of variance in Appendix Tables E-1 and E-2. The significances are also high but there is a slight drop for day temperature in both harvests. This drop was caused by the low significance in the 32 C day temperature plants. Night temperature again has a much higher F-value.
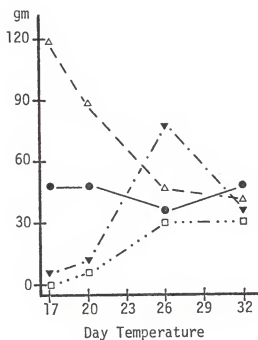
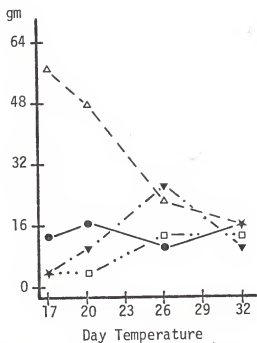Fig. 101. Leaf dry weight for the second harvest by day temperature.
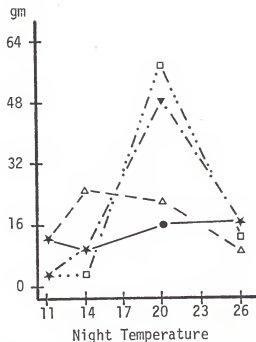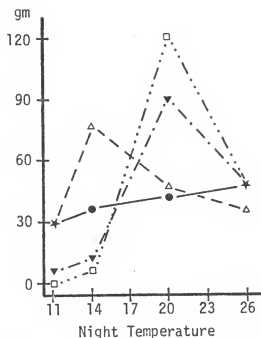
Fig. 102. Leaf dry weight for the second harvest by night temperature.

| ● = 26 C | △ = 20 C | ▼ = 14 C | □ = 11 C night | ★ = several points |
| ● = 32 C | △ = 26 C | ▼ = 20 C | □ = 17 C day | |
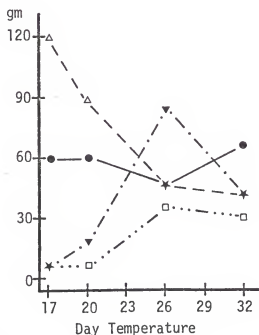
Fig. 103. Leaf dry weight for the final harvest by day temperature.
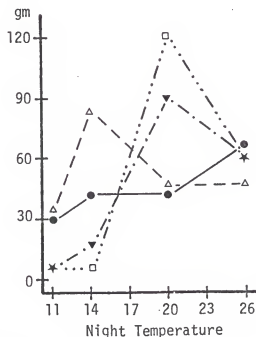
Fig. 104. Leaf dry weight for the final harvest by night temperature.

Figures 99 and 100 are graphically similar for both harvests. They more closely resemble the figures for stem dry weight (Figs. 87 and 88) than for root dry weight (Figs. 75 and 76). There is a high value for the 20 C night group plants (Appendix Table D-2) due to the 17/20 and 20/20 treatments and the sharp drop in the 26 C group is a reflection of the high pod production of these plants (see discussion for stem dry weight). The low leaf growth for the cooler treatments coincides with that for stem growth (Appendix Tables D-1 and D-2).

The increase in leaf growth in the 17/26 temperature treatment again substantiates Fortanier's (1957) findings that a low day-high night temperature regime increases growth. In the 26 C night temperature treatments, though, leaf dry weight did not show an increase with cooler day temperatures-warmer night temperatures. Wood (1968) found maximum leaf weight to occur in plants at a 25/25 temperature regime. His findings are in opposition to my research. A number of treatments have higher weight values. It must be remembered that an optimal leaf weight can only be determined by comparison with other plant components such as pod yield. A maximum value in numerical weight may not be advantageous for pod growth. This idea is discussed by Van Dobben (1962) when he states that yield increases are often caused by a shift in dry matter from one plant component to another. In my research, the best leaf weights occurred in the 26 C night plants and were quite similar.

Williams (1975) found his warmer site to produce the highest leaf weight. His treatments did not have the temperature ranges of my experiment and were not temperature controlled. As with stem

weight, whether or not leaf weight increases with temperature depends upon day-night temperature interactions in my experiment. Williams (1975) indicated that, in his experiment, leaf growth rate was reduced by start of reproductive growth and as pod growth became rapid, the leaf growth ceased completely. Visual observations in my research confirmed this for the warmer, larger pod load treatments. The leaf data also show a much lower increase in leaf weight for these warmer treatments after the second harvest than occurred before it.

Leaf Dry Weight Percentage

For day temperatures, 17 and 20 C show minimal significance at the 5% level and non-significance, respectively, at the second harvest (Appendix Table C-1). The low significances are gone by final harvest where all temperatures exhibit significance (Appendix Tables C-1, C-2, C-3, and C-4). However, the 17 and 20 C day temperatures have reduced R^2 values indicating an increase in variation (Appendix Table B-4). The second harvest night temperatures have reduced R^2 values. The only one having non-significance, though, is the 26 C temperature group. Unlike day temperatures, the group does not have significance by the final harvest. Some increase of R^2 values is noted at 14 and 20 C but the 26 C night temperature declined dramatically in R^2 and significance. The low 26 C group R^2 values and significances are mainly caused by the extremely uniform values of this group. Most treatments exhibit very low C.V. values, Appendix Table B-4.

Unlike many of the previous variables discussed, there are significant changes between the second and final harvests (Figs.

105, 106, 107, and 108). The major changes occurred in the four
26 C night temperature treatments. These treatments dropped in
value up to 10%. The 32/20 treatment also exhibited a major decrease.
All other treatments remained the same or dropped slightly except
the 26/11 treatment which increased 2%. A high night temperature
(26 C) appears to counteract the detrimental effect of low day
temperatures (Figs. 105 and 107).

The leaf dry weight percentage graphs have few of the general
treatment interrelationships of the other variables discussed.
The 20 C night temperature groups is the only one to show a sharp
"break-point" temperature. There also appears to be a general
decrease in percentage as night temperature increases in the final
harvest (Fig. 108). In the day temperature graphs (Figs. 105 and 107),
the differences between treatments in each day temperature group
become greater as the day temperature becomes higher. In the night
temperature graphs (Figs. 106 and 108), the lower night temperature
groups have approximately the same differences in percentage between
treatments while the 26 C groups exhibit reduced treatment differences
(Appendix Tables A-15 and A-16). There is no thermoperiodic effect
on the 26/26 treatment in the leaf dry weight percentage variable.
There was also no effect on the leaf dry weight variable.

The 17/20 and 20/20 treatments interestingly did not have high
percentages as was the case for stem dry weight percentage. Root
dry weight percentage for these treatments also did not have percentage
increases. It therefore appears that most of the dry weight increase
of these treatments was caused by increased stem growth and not by an
increase in the root or leaf fractions of the plants.
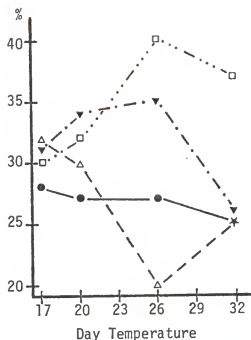
Fig. 105. Leaf dry weight percentage for the second harvest by day temperature.
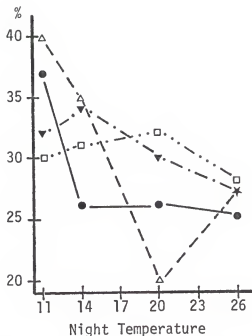
Fig. 106. Leaf dry weight percentage for the second harvest by night temperature.

● = 26 C	△ = 20 C	▼ = 14 C	□ = 11 C night	★ = several points
● = 32 C	△ = 26 C	▼ = 20 C	□ = 17 C day	
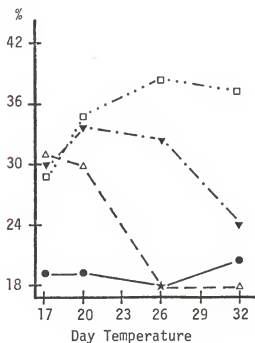
Fig. 107. Leaf dry weight percentage for the final harvest by day temperature.
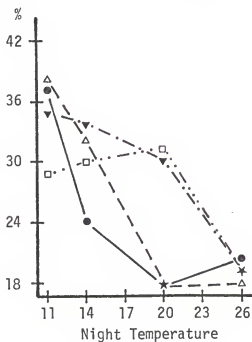
Fig. 108. Leaf dry weight percentage for the final harvest by night temperature.
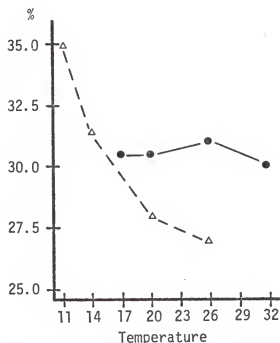
Fig. 109. Leaf dry weight percentage by day or night temperature group for the second harvest.

Fig. 110. Leaf dry weight percentage by day or night temperature group for the final harvest.

● = day temperature;　　△ = night temperature;　　★ = several points

Fig. 111. Total pod dry weight by day or night temperature group for the second harvest.

Fig. 112. Total pod dry weight by day or night temperature group for the final harvest.

For day and night temperature group means, day temperature in the second harvest is only minimally significant at 5% (Appendix Tables E-1 and E-2). Other F-values and the R^2 values are not as high as those of the other variables studied. All F-values are highly significant for the final harvest and the R^2 is higher than the second harvest value. The night temperature F-value increased greatly by the final harvest indicating a possible greater effect of night temperature than day on the leaf dry weight percentage variable.

The graph of night temperature points in Figs. 109 and 110 (Appendix Tables D-1 and D-3) resembles that for root dry weight percentage but not stem dry weight percentage. The graph of day temperature points resembles neither of the other percentage variables. The two harvests resemble one another except for a large decrease of the 26 C night plants in the final harvest. Smaller decreases also occur in all day temperatures in the final harvest except in the 20 C group. The 26 C night temperature decrease in the final harvest is caused by the treatments of this temperature producing large pod loads which are a large percentage of the total dry weight.

Fortanier (1957) states that, generally, the leaf takes the greatest part of the volume, weight, and area of the whole plant. Concerning leaf dry weight, his conclusions are not supported by my study. The stem fraction, except in cases of maximum pod load, usually had the highest weights of any plant fraction and usually had the highest percentage of total dry weights of all treatments.

Total Pod Dry Weight

This variable is the total weight of all pods produced less the
weight of all pegs as classified in the Materials and Methods. Four
treatments of the second harvest and three treatments of the final
harvest yielded no pods. The treatments with the highest means had
low C.V.s (Appendix Table B-4) while lower weight treatments had
C.V.s up to 200%. The C.V. values appear to be similar to those of
the other variables studied except for the high values of the low
mean weight, final harvest treatments. Figures 113, 114, 115, and
116 have marked changes between the second and final harvests.
These changes are not unexpected as most pod fill should occur
during the period between these two harvests. For the day tempera-
tures (Figs. 113 and 115), the two cooler night temperatures remain
graphically similar between harvests although the 32/14 treatment
increased slightly in weight (Appendix Tables A-15 and A-16). It
is important to remember that the 32/11, 20/20, and 17/20 treatments
never produced a second or final harvest and the termination harvest
was included in the analyses for both harvests. The 20 C night
temperature treatments have a similar graphical relationship in
both harvests except for the 26/20 and 32/20 treatments which increased
weight sharply. The 26/20 treatment has a higher dry weight than the
32/20 treatment indicating that at 20 C night temperature a day
temperature of 32 C is detrimental. The 26 C night treatments also
are graphically similar in each harvest with a nearly three-fold
increase in weight in all treatments (Figs. 114 and 116). No signif-
icance is found between 26 C night treatments in the second harvest

but the 17/26 treatment is significantly lower in the final harvest (Appendix Tables C-2 and C-4).

The second harvest has a low R^2 for 11 C night temperature but it is still significant. The significance level is approximately the same in the final harvest for 11 C. Both 14 and 20 C have high R^2 values and significances with the final harvest being the highest. The 26 C temperature group has a very low R^2 and non-significance at the second harvest; the group has an increased R^2 and has minimal significance at the 1% level at the final harvest. The significantly lower value of the 17/26 treatment at the final harvest can probably be accounted for by this treatment's very large production of pods; many of which never matured. The main filling period of the 17/26 treatment occurred during the lowest radiation and shortest day length period of the year. This fact probably caused many pods to never fill completely.

Treatments within the 17 and 20 C day temperature groups (Figs. 114 and 116) have similar interrelationships in both harvests. However, the 26 C night temperature plants at the 17 and 20 C temperatures had large increases in weight at the final harvest. The 26 C day treatments also are graphically similar at both harvests except for an almost four-fold increase in weight at 26/26. A large increase also occurred at 26/20.

While the 26/26 treatment had a large weight increase, one might expect a different relation than that shown in the figures. While all other day temperatures had a continued weight increase through 26 C night temperature (Figs. 114 and 116), the 26/26 treatment is lower or levels off. A lower value for 26/26 is also seen in Figs. 113 and 115 in relation to other 26 C night temperature
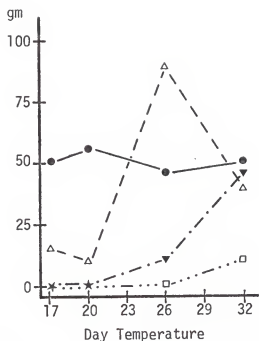
Fig. 113. Total pod dry weight for the second harvest by day temperature.
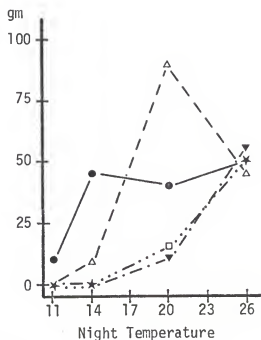
Fig. 114. Total pod dry weight for the second harvest by night temperature.

● = 26 C	△ = 20 C	▼ = 14 C	□ = 11 C night	★ = several points
● = 32 C	△ = 26 C	▼ = 20 C	□ = 17 C day	
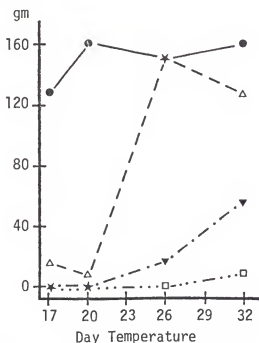
Fig. 115. Total pod dry weight for the final harvest by day temperature.
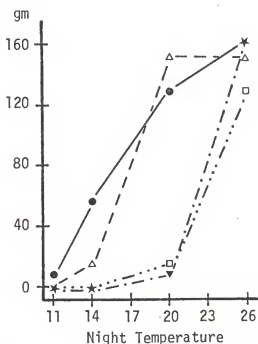
Fig. 116. Total pod dry weight for the final harvest by night temperature.

treatments. The drop is not statistically significant (Appendix
Tables C-1 and C-3). This lack of continued weight increase is likely
related to the direct effect of thermoperiodism on the pod weight
fraction of the 26/26 treatment and indirectly through the termo-
periodic effect on this treatment's root and leaf dry weights.

The 32 C plants are graphically dissimilar for the two harvests.
While only the 32/11 treatment is significant in the second harvest,
all treatments at the final harvest are significantly different.

Large differences are present between treatments of the various
day temperature groups (Figs. 113 and 115). The warmest and coolest
night temperatures, however, exhibit very little weight difference
between the treatments (Figs. 114 and 116). The most uniform graph,
in respect to each day temperature group's reaction to night temper-
ature, is Fig. 116.

The only night temperature group to exhibit the 20 - 26 day
temperature "break-point" is 20 C. The 26 C day temperature group
is the only one to have the 14 - 20 night temperature "break-point."
The 32 C day temperature groups shows only a continued weight increase
in the final harvest Fig. 116. A 20 - 26 night temperature break
occurs at the two lower day temperatures in Fig. 116.

Both harvests have similar graphs of day and night temperature
groups (Figs. 11 and 112). Appendix Tables D-2 and D-4 show that
both harvests are similar in the interrelationships of the treatment
values. There is a continued, significant increase in weight with
each increase in night temperature. No "break-point" is seen in
the night temperature groups. However, the 20/26 day temperature
"break-point" is clearly seen in these figures. It appears from

Figs. 111 and 112 and from Appendix Tables E-1 and E-2 that night temperature is again of primary influence. The final harvest has extremely high F-values and R^2 value.

In wheat, Spiertz (1974) found that high temperatures decreased yield due to high growth rates causing a lack of carbohydrates earlier in plant growth. At low temperatures, growth rates were slower and a longer time was needed before a carbohydrate shortage occurred. His work agrees with that of Dreyer (1980) on the effect of temperature on pod growth rate and yield in peanuts. The work also compares with research of McGraw (1977) on partitioning in various peanut cultivars.

Dreyer (1980) found seed weight to be significantly lower at 37 C continuous fruiting-zone temperature and significantly higher at 23 C. My research shows higher yields are obtained at 26 C night temperature regardless of the day temperature. While no exact measurements were made of pot and podding-box temperatures in my research, it is believed the temperatures should have closely approximated ambient air temperature in the treatments with the highest yields. In these treatments, full substrate cover was obtained and would have prevented substrate heating from direct solar radiation. Some thermocouple studies in the early part of the experiment showed that the bare-surfaced pots required a maximum of five hours to obtain the new temperature after transference from one temperature regime to another. However, the pots often obtained quite high temperatures due to the open surface. The podding-boxes, with less depth and more surface to the air, would not have reached such high temperatures and would undoubtably have cooled faster.

Spiertz (1974) found an acceleration of development, in wheat, to be more important than an increase in growth rate at high temperatures. The latter agrees with my research and Dreyer's (1980) study. Van Dobben (1962) states that final yield depends upon a plant's longevity. While the latter is true in optimal conditions, suboptimal conditions, as seen in my experiment, can alter the effect of longevity by reducing pod set. The 20/26 and 17/26 treatments both experienced elongated life cycles due to their temperature regimes. While the results of analysis do not show a significant difference between 20/26 and 32/26, it is probable that if the plants had been grown under more optimal radiation conditions, the 17/26 and 20/26 treatments would have significantly out yielded the 32/26 treatment. Both the 20/26 and 17/26 treatments probably experienced slower growth rates of the seeds thereby allowing more pods to be present. The reason for increased yield of the lower day temperature plants might be due to the inhibition of the enzyme system controlling phospho-glycolate production and therefore photorespiration.

Williams (1975) found seed yield to not be well related to mean temperature. His intermediate temperature regime produced the greatest yield. Chang (1974), Cheliadinova (1944), Gautreau (1973), Harris and Bledsoe (1951), Shear and Miller (1950), and Suzuki (1966) all found higher temperatures to increase yield. However, none experimented with high temperatures that would likely reduce yield (greater than 35 C). Chang (1974) found low temperatures to sharply reduce yield. Chang's work agrees with my experiment. Wood (1968) found that the effect of temperature on yield was due to its effect on the number of developing pegs. Wood's study agrees with my research.

Mature Pod Dry Weight

While the total pod dry weight measures the total pod production of the plant, it over-estimates the useful yield of the plant. Mature pod dry weight is the amount of pods that are of economic value. Therefore, mature pod dry weight is a better measure of actual plant yield.

Table B-5 shows that only eleven of the sixteen treatments produced mature pods by the experiment's conclusion. Of these sixteen, only the top six yielded large weights of mature pods. The C.V.s are quite low for the top six treatments while the treatments with lower yields exhibit very high C.V.s. The C.V. should normally increase as the mean value decreases if the variance is the same among all treatments. The low C.V.s of the higher treatments indicate that most error was eliminated from the experiment.

The second harvest figures (Figs. 117 and 118) are graphically similar to the second harvest total pod dry weight (Figs. 113 and 114). The final harvest graphs (Figs. 119 and 120) are almost identical to those of final harvest total pod dry weight. The similarity of the final harvest figures would be expected if the majority of pods are fully mature at final harvest. The second harvest day temperature graph discussion for total pod dry weight is applicable for this variable. The night temperature graphs are less similar. The 32/20, 17/26, 20/26, and 26/26 treatments lagged behind the other treatments in maturity at the second harvest. The low maturity of the 17/26, 20/26, and 26/26 treatments caused the 26 C night temperature group to have a greater dispersion of treatment values than was present for total pod dry weight. The high value of the 20/20 treatment is

due to the treatment being included in both harvests' graphs. Although the total pod dry weight and mature pod dry weight graphs are similar, the values are much lower in the mature pod dry weight graphs since most pods were still immature at the second harvest.

The final harvest graphs are almost identical to those for total dry weight. Tables A-16 and A-18 exhibit the same Duncan's MRT with rare exception. Therefore, the total pod dry weight discussion also applies here. Because of the similarity of all graphs of total pod dry weight and mature pod dry weight, the total pod dry weight discussion on comparison of the two harvests' data also applies to this variable.

The F-values, significances, and R^2 for the analysis of variance on mature pod dry weight (Appendix Tables E-1 and E-2) closely resemble the values of total pod dry weight. All values are significant.

Figures 123 and 124 for day or night temperature group means are quite similar to those for total pod dry weight. The only exceptions are the "leveling-off" of the 26 C night group and the slight increase in the 17 C day group of the second harvest (Appendix Tables D-2 and D-4). The "leveling-off" of the 26 C group is probably a result of the 20 C night value being abnormally high for the second harvest due to the inclusion of the 17/20 and 20/20 harvests. The 17 C group increase is probably caused by the 17/20 treatment having more pod weight than the 20/20 treatment (see Figs. 113, 115, 117, and 119).

The decrease in pod weight of the 20/20 treatment compared to the 17/20 treatment (Table A-17 and A-18) again substantiates the thermoperiodism in Florunner peanut. These treatments were similar in
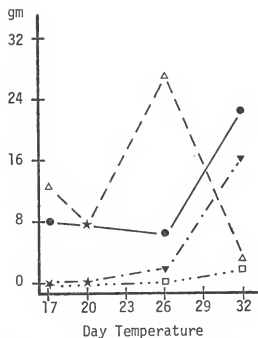
Fig. 117. Mature pod dry weight for the second harvest by day temperature.
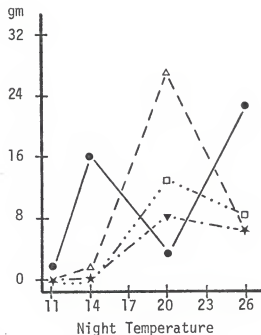
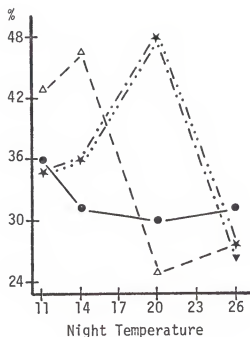Fig. 118. Mature pod dry weight for the second harvest by night temperature.

| ● = 26 C | △ = 20 C | ▼ = 14 C | □ = 11 C night | ★ = several points |
| ● = 32 C | △ = 26 C | ▼ = 20 C | □ = 17 C day | |
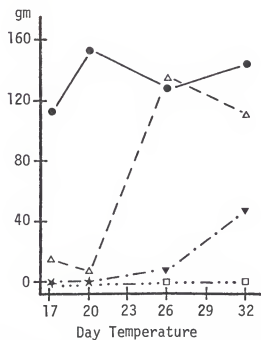
Fig. 119. Mature pod dry weight for the final harvest by day temperature.
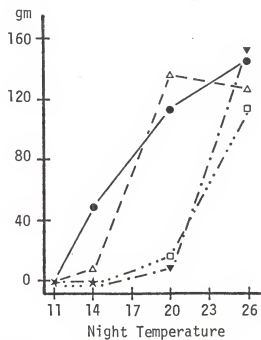
Fig. 120. Mature pod dry weight for the final harvest by night temperature.
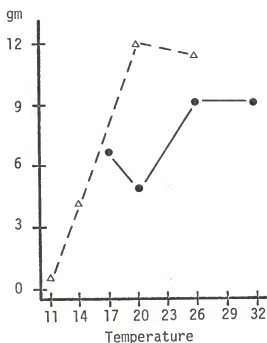
Fig. 121. Mature pod dry weight by day or night temperature group for the second harvest.

Fig. 122. Mature pod dry weight by day or night temperature group for the final harvest.

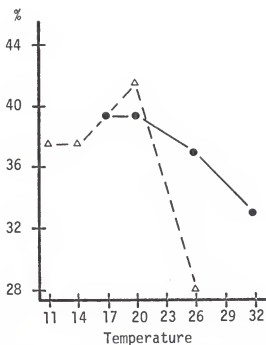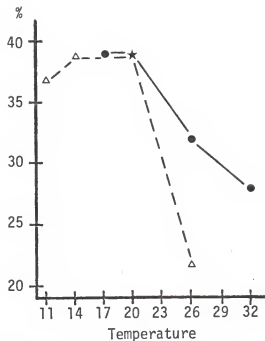● = day temperature;　△ = night temperature;　★ = several points

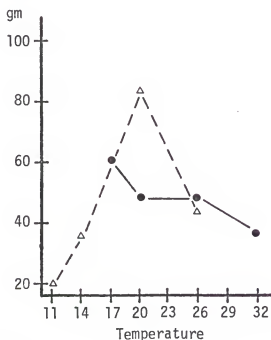Fig. 123. Mature pod dry weight percentage by day or night temperature group for the second harvest.

Fig. 124. Mature pod dry weight percentage by day or night temperature group for the final harvest.

growth habit and developmental characteristics, yet the 20/20 treatment shows a depression when its slight increase in temperature should give it an advantage.

The discussion of the literature in the total pod dry weight section applies equally as well for this variable. No literature was found dealing exclusively with mature seed or pod weight.

Mature Pod Dry Weight Percentage

This variable is a good indicator of the accuracy of the dates chosen for final harvest. It also indicates the maximum percent of pod dry weight at final harvest that one can expect as marketable yield for the Florunner variety. As discussed earlier, not all pods can be harvested mature. An estimation of the "best date" for harvest must be made in order not to lose too many first-formed pods while at the same time allowing most of the pods to fill. The percentage should decrease, under optimal conditions, as the filling period is extended. The longer the filling period, the more pods at inter- mediate stages of development will be present at harvest. But a longer filling period should increase the number of pods that can be filled. The latter has been shown by Dreyer (1980). With more pods to fill, the end percentage should be the same regardless of filling period length as long as the factor that influences the period length does not also influence the partitioning of photosynthate to the pods. No exact conclusions are possible in my experiment concerning the similarity of percentages since some treatments reached maturity under less than optimal radiation conditions.

Because of the lack of pod production in some treatments, percentages were only calculated for twelve of the second harvest

treatments and thirteen of the final harvest treatments. The C.V.s (Appendix Table B-5) were much lower for the final harvest than for the second. Lower final harvest C.V.s were also present in mature pod dry weight. Large variation would be expected at the stage of plant growth represented by the second harvest. Some of the final harvest treatments show extremely low C.V.s indicating that weight percentage of mature pods is a constant between plants of the same treatment.

There are marked differences between the figures for the second harvest and those for the final harvest (Figs. 125, 126, 127, and 128). The differences would be expected since most pod fill occurred after the second harvest. Figure 123 presents interesting treatment interrelationships. A day temperature of 32 C appears to have speeded development of the pods in all night temperature groups except the 20 C. It should be remembered, though, that the same 17/20 and 20/20 treatment values are included in the 20 C group both the second and final harvest analyses. The high maturity percentages of the 17/20 and 20/20 groups are easily seen in Fig. 126.

The cooler day temperatures had the same effect on the 26 C night group percentages (Fig. 128, Table A-20). The reason for the delay in maturity of 32/20 treatment is unknown as is the reason for the 26/20 group having a higher maturity percentage than 26/26 (Figs. 125 and 126). The lower 26/26 value may be related to thermoperiodism. By final harvest (Fig. 127) both 26 and 20 C night temperatures had matured rapidly (the 32/20 treatment being the most rapid). Both groups show little or no significance between treatments (Appendix Table A-20). The 14 and 11 C groups show increased maturity

as day temperature increases. The treatments 32/11, 26/11, 26/14, and 20/14 never exhibited full plant maturity due to experiment termination. Although the 17/20 and 20/20 treatments never stopped flowering completely, their pod loads were apparently ready for harvest by experiment termination.

Figure 126 shows variable maturity for the treatments of 32 and 26 C day temperature groups. No clear relation exists for these groups. However, the maturity delay of the 32/20 and 26/26 treatments can be seen. Both the 26 and 20 C night temperatures (Fig. 128) have very similar percentages (Table A-20). The 32/14 treatment percentage is almost as high as the 20 and 26 C night group percentages (Appendix Tables A-19 and A-20). An increase in maturity of the cooler treatments occurs as the night temperatures increase.

Figures 123 and 124 for day or night temperature group means show that the second harvest varies considerably from the final harvest. The figures and their corresponding percentage values (Appendix Tables D-2 and D-3) must be studied with caution. Several of the group means are artificially high or low because of missing treatments and because several treatments were not fully mature due to experiment termination. It appears that as day temperature increases, the percent decreases. However, the 17 C day group had only two treatments that produced pods while the 20 C day group had three. The low number of treatments in these groups causes an increase in the mean values since the treatments that are present have high percentages. And, the 17/20 and 20/20 treatments each contain eight values. The 32 C day treatment group has seven values for the 32/11 treatment which causes a somewhat lower mean value. It is likely that day temperature did not exert

Fig. 125. Mature pod dry weight percentage for the second harvest by day temperature.

Fig. 126. Mature pod dry weight percentage for the second harvest by night temperature.

| • = 26 C | △ = 20 C | ▼ = 14 C | □ = 11 C night | ★ = several points |
| • = 32 C | △ = 26 C | ▼ = 20 C | □ = 17 C day | |
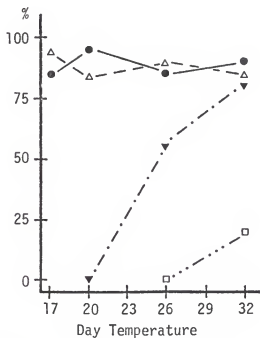
Fig. 127. Mature pod dry weight percentage for the final harvest by day temperature.
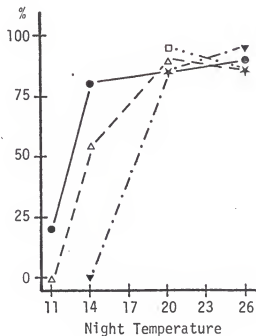
Fig. 128. Mature pod dry weight percentage for the final harvest by night temperature.

as great an influence on mature pod dry weight percentage as did night temperature. Appendix Tables E-1 and E-2 show the latter to be the case for the final harvest but not the second. The missing cells in the analysis of variance of mature pod dry weight percentage somewhat confused the effects of day and night temperature. The R^2 values for both harvests are not as high as those of the other variables studied indicating a reduced effect of temperature on this variable and/or increased variability. Since the C.V.s (Table B-5) are low, it would appear that the former is the case. Day-night interaction has decreased significance in the final harvest. This reduced significance is undoubtably due to the decreased effect of temperature on the mature pod weight variable as indicated by lower F-values.

The problem with missing treatments also exists for night temperature values of Figs. 123 and 124. The 11 and 14 C temperature groups are artificially low. Nevertheless, percentage values basically increase with increasing temperature. No accurate estimation of a relation for day temperature groups can be made. In comparing the second harvest with the final, the 26 C day and 26 C night groups are seen to have a large increase in percentage in the final harvest. The latter indicates that the 26 C day and night groups, as a whole, were somewhat slower to mature and that most pod fill occurred after the second harvest. The "break-points" shown for some of the previously discussed variables did not appear in the mature pod dry weight variables.

My research shows that an average of 90% of total pod dry weight is harvestable as mature yield for the Florunner peanut. This value is constant over a wide range of conditions. No literature is available on the percentage of mature pods or seeds.

Total Pod Number

While pod weight measures the economic yield that is produced
by the peanut plant, pod number indicates the peanut plant's potential
for yield. A lack of pods can prevent a plant from reaching its full
yield potential. Conversely, not all pods produced may reach full
maturity.

Unlike the pod dry weight variables, total pod number shows
similarity between harvest dates (Figs. 129, 130, 131, and 132).
Treatment 17/26 produced the largest number of pods (Tables A-21 and
A-22). The 26 C night temperature group showed decreasing numbers
as the temperature increased. The cause of this increase may be
related to enzyme inactivation at cooler day temperatures inhibiting
photorespiration. The cooler night temperatures did not exhibit the
number increase at cooler day temperatures. In the case of the
cooler night temperatures, overall inhibition of growth and develop-
ment was probably the most important factor. The cooler night
temperatures increased pod number as day temperature increased
(Fig. 129). The 26/20 treatment produced a significantly larger
number of pods than 32/20 (Table A-22) and the dry weight yield of
mature pods was significantly larger (Table A-18). The latter
32/20 treatment effect indicates that at night temperature of 20 C,
32 C day temperature is detrimental to yield.

The graphs by day temperature (Figs. 129 and 131) show that pod
numbers increase with each increase in night temperature. No inter-
action (crossover) is present in Figs. 129 and 131. However,
interaction is present in the graphs by night temperature (Figs. 130
and 132). For 20 C night, the 32 C temperature has a significantly

lower number of pods than the 26 C day temperature (Appendix Table A-22). At 26 C night, the lower day temperatures invert the order seen in the cooler night temperatures. That is, pod number increased from the warmest to the coolest day temperatures.

The critical "break-point" between 20 and 26 C day temperatures is seen for both the 26 and 20 C night groups (Fig. 131). The "break-point" temperature has the opposite effect in the 26 C night temperature group than it does in the 20 C night group. Only the 26 C day group exhibits the 14-20 C night temperature "break-point" although another critical point is seen between 20 and 26 C night for the two cooler day temperatures (Figs. 130 and 132).

All night temperature groups have high R^2 values and are significant at the 1% level in both harvests (Appendix Tables C-2 and C-4). There is some reduction in R^2 values for the 11 and 26 C night temperatures in both harvests compared to the 14 and 20 C temperatures. The reduction is probably related to the lower significance between treatments (Table A-22) of both temperatures. The day temperature groups have high R^2 values and significances for both harvests (Tables C-1 and C-3).

The C.V.s for each treatment, (Appendix Table B-6) are higher than those seen for many of the vegetative component weight variables but lower than those for the pod dry weight variables. Some decreases are noted at the final harvest. The treatments with the higher pod numbers have the lower C.V.s as is expected.

The graphs of the means of day and night temperature groups (Figs. 133 and 134) are similar for both harvests. Day temperature, night temperature, and day-night interaction were all highly significant.

180
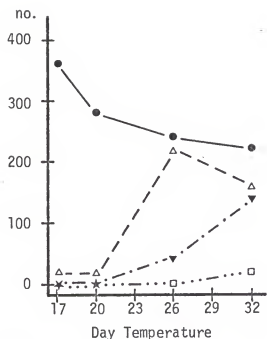
Fig. 129. Total pod number for the second harvest by day temperature.
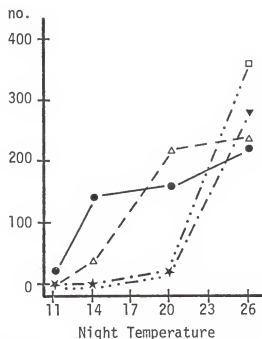
Fig. 130. Total pod number for the second harvest by night temperature.

| ● = 26 C | △ = 20 C | ▼ = 14 C | □ = 11 C night | ★ = several points |
| ● = 32 C | △ = 26 C | ▼ = 20 C | □ = 17 C day | |
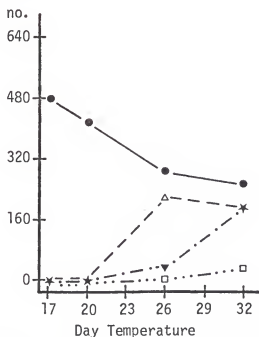
Fig. 131. Total pod number for the final harvest by day temperature.
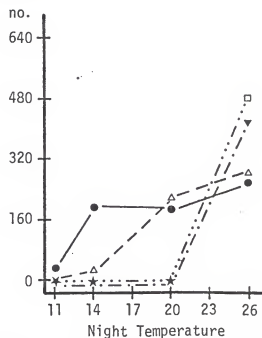
Fig. 132. Total pod number for the final harvest by night temperature.
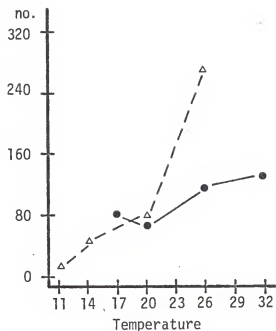
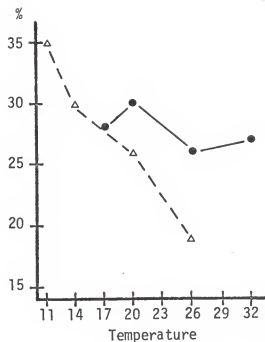Fig. 133. Total pod number by day or night temperature group for the second harvest.
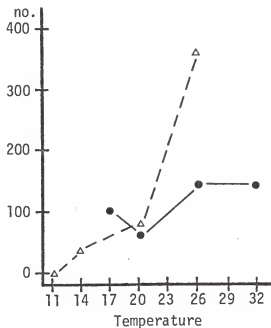
Fig. 134. Total pod number by day or night temperature group for the final harvest.

● = day temperature; △ = night temperature; ★ = several points
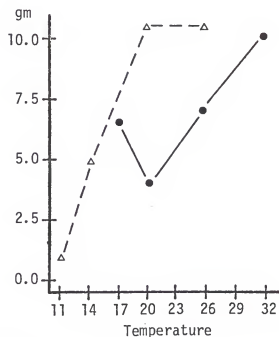
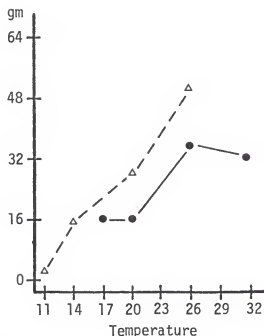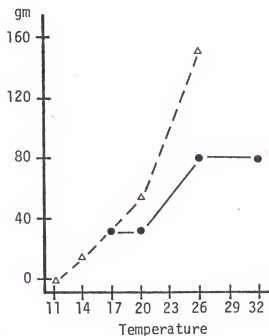Fig. 135. Mature pod number by day or night temperature group for the second harvest.
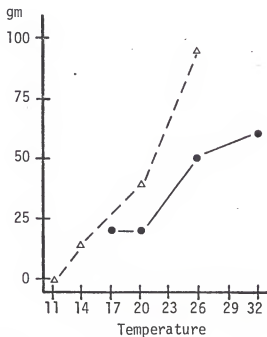
Fig. 136. Mature pod number by day or night temperature group for the final harvest.

Appendix Tables E-1 and E-2 show that both harvests have high R^2 values. The F-value for night temperature is much greater than day temperature. As with previous variables, this high value may indicate a greater effect of night temperature. A day temperature of 17 C shows a significant increase in pod number over the value of the 20 C day group (Appendix Tables D-2 and D-4). The increase is caused by the very high pod numbers of the 17/26 treatment. Day temperature exhibits the 20 - 26 C critical temperature "break-point" while the night temperature "break-point" is not present. The high pod number mean for the 26 C night group is caused by the high values of the 17/26 and 20/26 treatments.

Dreyer (1980) concluded that as temperature is lowered, individual pod growth rate is lowered, thereby increasing the number of pods that can be produced from available photosynthate. His constant temperature treatments were applied only to the fruiting zone. No difference was found between the total dry weight of the treatments since the temperatures were not applied to the whole plant. Dreyer's results showed a significant increase in pod number as the temperature was lowered from 27 to 23 C. While my research varies from Dreyer's in the respect that variable day/night temperatures were used and were also applied to the plant tops, comparisons can be made. The 26 C night temperature group (the only treatments, excluding the 32/20 treatment that had mean values above Dreyer's lowest treatment of 23 C) showed increasing pod number as day temperature decreased. Day temperatures did not show a pod number increase with decreasing night temperatures (Figs. 130 and 132). The 20 C night temperature also showed a pod number increase from 32 C to 26 C day temperature. The latter increase

agrees with Dreyer's (1980) work as the 26/20 treatment's mean temperature is lower than the 32/20 treatment mean temperature. It is difficult to make exact comparisons of the experiments. The experimental conditions were quite different and the effect of varying temperatures and of temperature on plant tops greatly affected the final pod yield and number in my experiment.

Bolhuis and De Groot (1959) found the greatest pod set to be between 27 - 30 C constant temperature. Suzuki (1966) found more pods at higher air and soil temperatures. Jacobs (1951) showed pegs to be formed more rapidly yielding a greater number at a temperature combination of 26/27 than at 26/30.

For studying the effect of soil temperature on pod growth and development, Dreyer's (1980) work is the most valid. My research and the research by Bolhuis and De Groot (1959) and Suzuki (1966) are confounded by the earlier mentioned temperature effect on plant tops.

Mature Pod Number

While total pod number is a measure of the plant's potential for yield, the number of mature pods is the amount of useful produce that the plant actually yielded. Figures 137, 138, 139, and 140 are markedly different from the graphs of total pod number.

Since most pod fill occurs after the cessation of flowering, the graphs for mature pod number are quite different for the two harvests. Figure 137 shows that the 32/26, 32/14, and 26/20 treatments had a greater number of mature fruit at the second harvest than other treatments. However, there was only a short time between

the second and final harvests for the 32/14 treatment. The 26/20 treatment has a larger number of total pods than many of the other treatments. The large number of pods partially accounts for the high mature pod number. Most pods in the 32/20 treatment filled to maturity after the second harvest.

Treatment 26/20 produced more mature pods than the 32/20 treatment (Figs. 139 and 140). As seen earlier, the 26/20 treatment also had the higher yield. Apparently 32 C day temperature is detrimental to yield at a night temperature of 20 C. The 26/26 treatment exhibits a possible thermoperiodic effect. The pod number in the 26/26 treatment was significantly lower (Appendix Table A-22) than two of the other 26 C night temperature treatments (Fig. 139). The 17/26 treatment also produced a smaller number of mature pods. The 17/26 treatment was apparently hampered by the filling period continuing through December when solar radiation was at a minimum.

For day temperatures (Figs. 137 and 139) the 26/20 and 32/26 treatments have the largest increases in mature pod number. Treatment 32/20 also has a large increase that graphically surpasses many of the other treatments. As a group, the 26 C night temperature treatments had the greatest increase   indicating that most pod fill in these plants occurred after flowering cessation. The 32/26 and 26/20 treatments produced the largest number of mature pods. The latter treatments were significantly larger (Appendix Tables A-21, A-22, and B-6) than all other treatments.

The R^2 values for separate day temperature groups were much lower in the second harvest than the R^2 values seen for many of the previous variables studied. The mature pod number R^2 values

correspond quite closely, as expected, to the mature pod weight R^2 values (Appendix Table C-1). Minimal significance at the 1% level is seen for the 17 C day temperature. The cause of the low R^2 values is probably the high variation present in the second harvest. All day temperature groups have high R^2 values and signif-icances for the final harvest (Appendix Table C-3). Only the 20 C night temperature exhibits the 20-26 C day critical "break-point" (Fig. 139). The 32 C day group shows significance between all treatments (Table A-22).

For night temperatures, the graphs show marked differences. As a group, the 26 C night plants increase the most in mature pod numbers (Figs. 138 and 140). The large increase in the 32/20 treat-ment is obvious in Fig. 140. Both day and night temperature graphs indicate that pod number, with few exceptions, increase as day or night temperature increases. The 32/20, 26/26, and 26/20 treatments exhibited temperature interaction characteristics that cause a variation from the increasing-temperature-equals-increasing-pod-number trend. It is possible that if the 20/26 and 17/26 treatments had matured during a period of optimal solar radiation, they would have produced the highest pod numbers and highest yields. If the latter treatments had yielded more, a unique graphical relation resembling total pod numbers would have been formed for the 26 C night temperature group. Mature pod number would decrease as day temperature increases.

The R^2 values for separate night temperatures are quite low in the second harvest (Table C-2). The day temperatures within night temperature group 14 C are non-significant at the 1% level while 11 C has no significance. The reason for the low values is probably
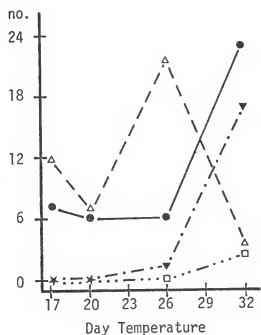
Fig. 137. Mature pod number for the second harvest by day temperature.
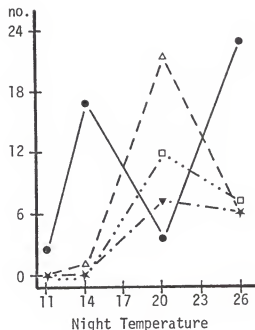
Fig. 138. Mature pod number for the second harvest by night temperature.

| ● = 26 C | △ = 20 C | ▼ = 14 C | □ = 11 C night | ★ = several points |
| ● = 32 C | △ = 26 C | ▼ = 20 C | □ = 17 C day | |
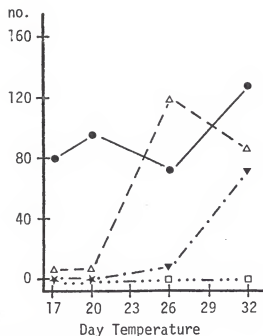
Fig. 139. Mature pod number for the final harvest by day temperature.
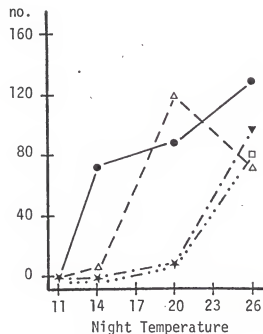
Fig. 140. Mature pod number for the final harvest by night temperature.

increased variation in the second harvest. The 26, 20, and 14 C groups all show high R^2 values and significances for the final harvest. However, the 11 C group still has non-significance and a very low R^2 value. In the 11 C group, the low values are caused by little difference between the treatment means and not variability. Only the 26 C day temperature was affected by the 14 - 20 C critical night "break-point" temperature.

The C.V.s for the final harvest in Appendix Table B-6 are similar to those for total pod number. The second harvest C.V.s are much larger than those for the final harvest or those of the second harvest total pod number. The high values for the second harvest are expected as some plant to plant variation in maturity is normal. If all treatments and plants within the experiment experienced constant variation, the lower mean values of the second harvest would also cause high C.V. values.

There are differences in the effects of day or night temperature between the second and final harvests (Figs. 135 and 136). Appendix Tables E-1 and E-2 show that day and night temperature and day-night interaction have high significance in both harvests. The analysis of variance R^2 value for the second harvest is much lower than that of the final harvest due to variation present in the second harvest. The night temperature F-values are only slightly larger than the day temperature values. The similarity indicates an equal effect of both day and night temperature.

The 26 C night temperature exhibits a sharp increase between harvests caused by the late pod fill of this temperature's treatments. The 17 C day group has a relatively lower increase of pod

number when compared to the other day temperature groups. The lower increase is caused by an artifact of the many immature 17/26 pods. Only the day temperature groups of the final harvest have the critical day temperature "break-point" effect.

Analysis of the mature pod number data must be tempered with the knowledge that a number of treatments had their maximum pod fill growth period during the time of the year with the least solar radiation. Except for the latter restriction, all authors' findings cited in the total pod number discussion are also valid for the mature pod number variable.

Mature Pod Number Percentage

As mature pod weight percentage is an estimate of the percent of reproductive dry weight (photosynthate) harvestable as economic yield, the mature pod number percentage is an estimate of the number of pods harvestable relative to total pod number. While the percentage of immature pods is of little importance if the immature pods are small and little photosynthate is lost, it indicates a potential for a greater number of mature pods. If one accepts the rationale that greater pod production, given equal pod size, provides a possibility for greater yield, then it might be possible to increase yield by increasing the percentage of the pods that fill to maturity. This percentage increase could be brought about by a shortening of the flowering period with equal pod production and a concurrent lengthening of the filling period with a slower pod fill rate. Unfortunately, my experiment indicates that some lengthening of the flowering period usually accompanies a longer filling period. While pod fill rate was not studied in my experiment, results from Dreyer (1980)

indicate that a slower pod fill rate would have been found in treatments with longer filling periods.

The mature pod number percentage graphs (Figs. 141, 142, 143, and 144) are quite different from the graphs for total and mature pod numbers. The uniformity of Figs. 141 and 142 indicates that all treatments filled similar percentages of their pods by flowering cessation. The similarity of percentages is an interesting phenomenon but not unexpected if there is a direct relationship between filling rate and the length of the flowering period. However, the graphs are somewhat misleading since the high values for the 17/20 and 20/20 treatments cause all other treatments to be plotted within a small area. The high values for the 17/20 and 20/20 treatments are caused by these treatments never showing end-of-bloom criteria and being including in both harvests' analyses. The 32/11 treatment also never reached flowering cessation but it did not produce a high number of mature pods by experiment termination. The reason is unknown. Tables A-25 and A-26 show that some significance is present although the percentages are quite similar.

Appendix Table C-1 shows that the 26 C day temperature group has a low R^2 and significance level compared to many of the previous variables studied. Treatment group 26 C day is, nevertheless, significant at the 1% level. The 32 C group night temperatures have no significance. The lack of significance is attributable to small differences between treatment means and high variability as shown in the C.V. values of Table B-7. The higher R^2 values and significance of the 17 and 20 C groups is caused by the high 17/20 and 20/20 treatment values. Day temperature exhibits

non-significance at both 11 and 14 C night temperature (Table C-2). Groups 20 and 26 C have lower than normal R^2 values but are highly significant. The 20 C group has the highest R^2 because of the presence of the 17/20 and 20/20 treatments. The low values for 11 and 14 C are caused by high variability in the second harvest and by the 11 and 14 C groups containing only two treatments instead of the normal four.

Final harvest (Figs. 143 and 144) presents a completely different graphical representation from the second harvest. Treatments 17/20 and 20/20 had values significantly higher (Tables A-25, A-26, and B-7) than other treatments. The 17/20 and 20/20 treatments will be excluded from discussion because of their unique characteristics. The highest day and night temperatures have the highest percentages except in the 26 C and 20 C night temperature groups. In the 26 C day group, both 26/20 and 26/14 have larger percentages than the 26/26 treatments. It is probable that the low value for 26/26 is related to thermoperiodicity. In the 20 C night group, the 26/20 treatment percentage is greater than the 32/20 treatment value. The lower 32/20 treatment value substantiates detrimental effect of 32 C day temperature at 20 C night on yield (see discussion on other reproductive component variables).

The treatment C.V. values decreased in the final harvest (Appendix Table B-7) but are still relatively high when compared with most of the other variables studied. The C.V.s should be calculated for only eleven of the sixteen treatments. The R^2 and significance values of the temperature groups continue to be low for the final harvest (Appendix Tables C-3 and C-4). Both 11 and 14 C night
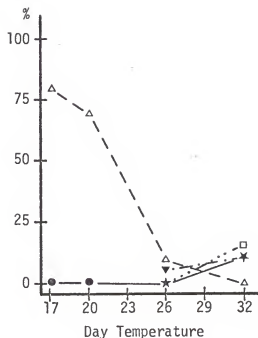
Fig. 141. Mature pod number percentage for the second harvest by day temperature.
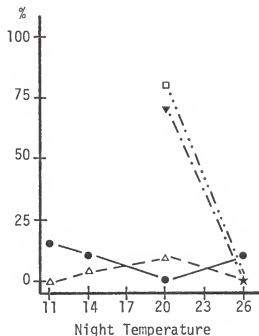
Fig. 142. Mature pod number percentage for the second harvest by night temperature.

| ● = 26 C | △ = 20 C | ▼ = 14 C | □ = 11 C night | ★ = several points |
| ● = 32 C | △ = 26 C | ▼ = 20 C | □ = 17 C day | |
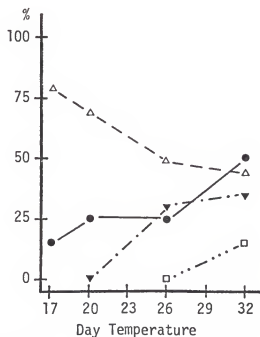
Fig. 143. Mature pod number percentage for the final harvest by day temperature.
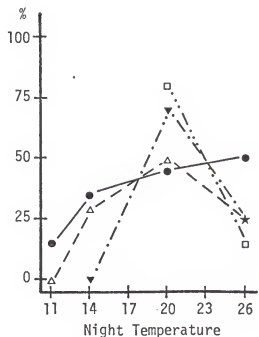
Fig. 144. Mature pod number percentage for the final harvest by night temperature.
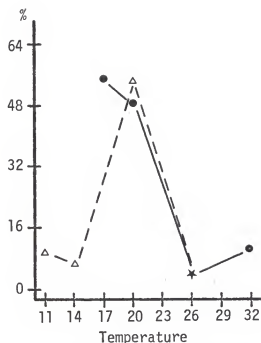
Fig. 145. Mature pod number percentage by day or night temperature group for the second harvest.
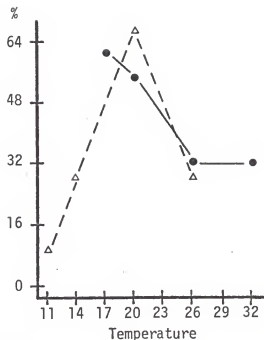
Fig. 146. Mature pod number percentage by day or night temperature group for the final harvest.

● = day temperature; △ = night temperature; ★ = several points
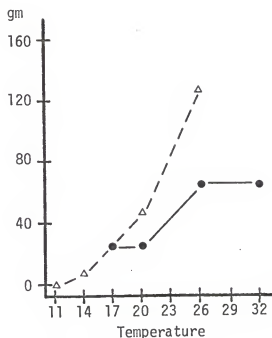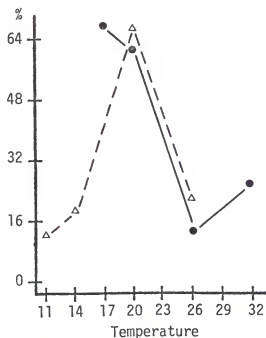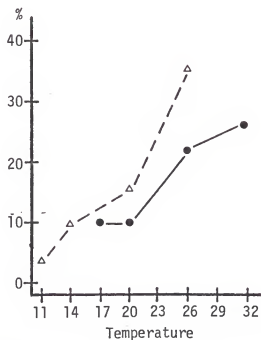
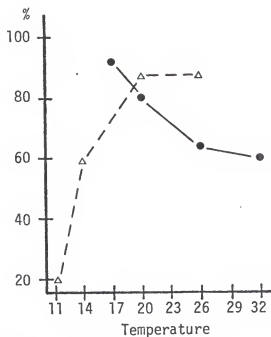Fig. 147. Reproductive dry weight percentage by day or night temperature group for the second harvest.
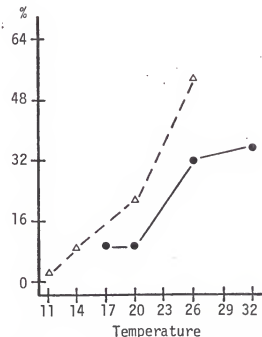
Fig. 148. Reproductive dry weight percentage by day or night temperature group for the final harvest.

temperature groups are non-significant although treatment means
vary up to 30% (Table A-25). Non-significance is partially caused
by the 11 and 14 C groups having less than four treatments. All
day temperature groups have high significance although the R^2
values for all but 17 C are relatively low compared with the R^2
values of many of the other variables studied.

Appendix Tables E-1 and E-2 list high significance for day and
night temperature and for day-night temperature interaction in the
second harvest; however, day temperature is non-significant for the
final harvest while both night temperature and day-night interaction
show high significance. The non-significant day temperature partial
sum of squares indicates that day temperature added no more accuracy
to the analysis after night temperature and day-night interaction
had entered into the equation. Therefore, in the final harvest, day
temperature did not have a major influence on the mature pod number
percentage. Non-significance does not mean that there is no signifi-
cant differences between day temperatures. Appendix Tables D-2 and
D-4 show that significant differences between the day temperatures
do exist.

Although large differences are seen between Figs. 141 and 143
for day temperature and Figs. 142 and 144 for night temperature,
the mean temperature groups' Figs. 145 and 146 are similar. The
20 C and 11 C night temperatures are artificially high in the second
harvest graph due to the presence of the 17/20, 20/20, and 32/11
treatments. The 14 C night temperature group increased in percentage
while the 11 C group remained about the same because of the presence
of the 32/11 treatment in the analysis of both harvests. The 26 C
night group showed a large increase in percentage.

As night temperature increased to 20 C, the percent mature pods increased. The 26 C night temperature was an exception to the increase. The low percentage values of the 17/26 and 20/26 treatments lowered the mean for the 26 C group. As day temperature increased, the mature pod number percentage decreased. The day temperature effect is partially modified by the high 17/20 and 20/20 treatment values and the low 32/11 value. Day temperature appears to exhibit the 20 - 26 C critical "break-point."

The day and night temperature trends discussed in the preceding paragraph must be viewed with caution. The uniqueness of the 17/20, 20/20, and 32/11 treatments and the interaction of low solar radiation during the filling period of several treatments precludes exact judgements and creates major problems in the analysis of this data. There is a strong possibility that the 17/26 and 20/26 treatments would have had higher percentages had light intensity not been limiting. There is no available literature on the percent maturity of peanut pod numbers.

Reproductive Dry Weight Percentage

The amount of economic yield obtained from a plant depends not only on growth and development conditions, but on the percentage of photosynthate partitioned to the plant component used for that yield. Recent studies (McGraw, 1977 and 1979; Dreyer, 1980) indicate that under normal growth conditions the percentage of assimilate partitioned to peanut fruit is a characteristic of the variety. Dreyer (1980) discovered the partitioning to remain the same under varying soil temperatures when the plant tops were grown under the same conditions.

McGraw (1977) found Florunner to partition approximately 80% of its photosynthate to the reproductive portions of the plant during the filling period.

Second and final harvest graphs (Figs. 149, 150, 151, and 152) are similar. Some similarity also exists between the day and night temperature graphs. The second harvest graph by day temperature shows that 26 C night temperature produced the highest percentages with the exception of the 26/20 treatment. No statistical differences were found between treatments of the 26 C group (Appendix Table A-28). The 32 C day temperature appears to be detrimental at 20 C night temperature as the 32/20 treatment value is significantly lower than the 26/20 treatment (Fig. 149). The two lower night temperatures show increased partitioning as day temperature increases. This increase is caused by higher pod production in the warmer treatments. It is not known whether the increased pod production was caused by a larger supply of photosynthate or a direct temperature effect on the mechanism controlling partitioning.

While percentages have increased and a few treatments have changed graphical position in relation to other treatments, the final harvest graph by day temperature (Fig. 151) is similar to the second harvest graph. The 32/20 treatment increased relatively more than the 26/20 treatment to become non-significantly different from the 26/20 treatment (Tables A-27 and A-28). The 26 C night temperature group exhibits significance between all day temperatures in the final harvest. Interestingly, the 26/26 treatment had the highest partitioning percentages. The lack of depression of the 26/26 value is in contrast to the thermoperiodic effect seen for other variables.

Both the 20/26 and 17/26 treatments decrease in partitioning percentages compared to other 26 C night temperature treatments. If the 17/26 and 20/26 treatments had matured during a time of high solar radiation, it is probable that the 26 C group would show a different relation with the 17/26 treatment having the highest partitioning.

Both the 20 and 14 C night temperature groups exhibited the 20 - 26 C day temperature "break-point" in both harvests. The 26 C night group shows no significance and a low R^2 value in the second harvest (Appendix Table C-2) and the 11 C group has a reduced R^2 value. The other two groups show high significance in Table C-2. The R^2 reductions are caused by a number of treatments having similar mean values. By the final harvest, only the 11 C night group had a reduction in R^2 (Table C-4). All groups are statistically significant in the final harvest. Appendix Table B-7 shows moderate C.V. values for both harvests. There is some general reduction in C.V. in the final harvest. The C.V.s are intermediate in value when compared to the other variables studied.

In the second harvest's night temperature graph (Fig. 150), the 26/20 treatment has an increased partitioning over that of the 26/26 treatment. However, by the final harvest the 26/26 treatment has surpassed the 26/20 treatment (Figs. 150 and 152). The 32/20 treatment has a larger increase between the two harvests relative to the increases of other 32 C day temperature plants. The 14 - 20 C critical "break-point" is found in the three lower day temperature groups. Appendix Table A-27 shows that significance exists between the 14 and 20 C night temperatures of the three groups. With the exception of the 32/26 treatment, all temperature groups in the final harvest
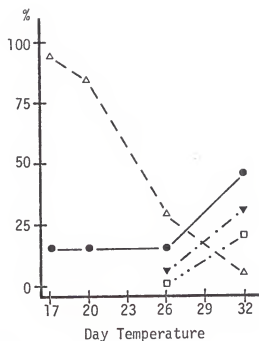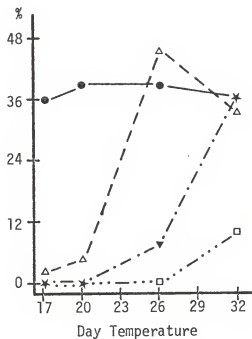
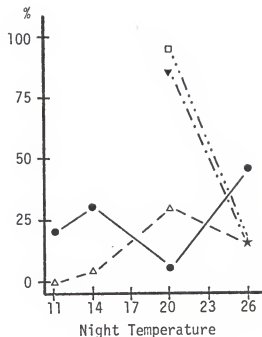Fig. 149. Reproductive dry weight percentage for the second harvest by day temperature.
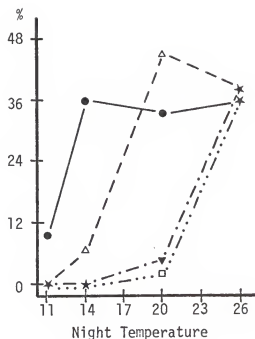
Fig. 150. Reproductive dry weight percentage for the second harvest by night temperature.

| ● = 26 C | △ = 20 C | ▼ = 14 C | □ = 11 C night | ★ = several points |
| ● = 32 C | △ = 26 C | ▼ = 20 C | □ = 17 C day | |
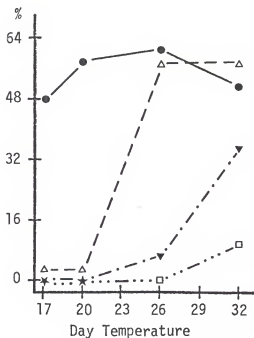
Fig. 151. Reproductive dry weight percentage for the final harvest by day temperature.
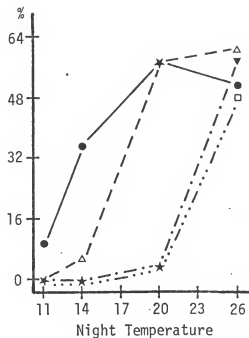
Fig. 152. Reproductive dry weight percentage for the final harvest by night temperature.

increase in percentage as temperature increases (Fig. 152). It appears that 26 C night temperature is not as advantageous as 20 C for a day temperature of 32 C. With the exception of a slightly lower R^2 value for the second harvest's 32 C group, all groups of the second and third harvests have high R^2 values and significances for the night temperatures (Tables C-1 and C-3) of the day temperature groups.

Day and night temperature and day-night interaction are highly significant in both harvests (Appendix Tables E-1 and E-2). The R^2 values are also quite high. F-values for day and night temperatures were similar in the second harvest while night temperature has the larger value in the final harvest. Night temperature appears to have a slightly stronger effect on partitioning.

Except for larger values in the final harvest, day and night temperature group means show identical graphical relations in Figs. 147 and 148. Day temperatures exhibit the 20 - 26 C day critical temperature "break-point." The 14 - 20 C night "break-point" is not present. All night temperature values are significantly different from each other. The two lower day temperatures are not significantly different (Appendix Tables D-2 and D-4). Both figures indicate that the percent partitioning increases as temperature increases.

If one accepts that the potential partitioning of a peanut variety is set, then variances from the set value must be caused by factors external to the plant. Such was the case in my research. Four of the top yielding treatments (Tables B-5 and B-7) had similar partitioning values. McGraw (1977) calculated Florunner's partitioning

to be approximately 80% during the pod filling period. Because his data did not take into account root growth and was determined for the filling period only, the value of 60% found in my experiment appears to be comparable.

The 20/26 treatment shows a non-significantly lower value possibly caused by the treatment maturing during a period of low solar radiation. Treatment 17/26 is significantly lower at 48%. This treatment's yield was depressed by the low radiation. If the partitioning percentage of the 17/26 treatment had equaled that of the 26/26 or 32/20 treatments, it is probable that this treatment would have yielded higher than the 20/26 treatment. The partitioning percentage will be lower during a period of lower solar radiation if one considers that the vegetative portion of the plant is continually using a set amount and not a specific percentage of photosynthate for maintenance. The partitioning percentage will also be lower if the plant develops under high radiation prior to the start of reproductive growth and then under low radiation during reproductive growth.

Treatments below 17/26 (Table B-7) show a sharp decrease in percentage. These decreases are caused not by decreasing solar radiation but by the effects of temperature on total photosynthate production or the development of pegs and pods. Total dry weight decreased in many of these treatments.

The effects of temperature on flowering, fertilization, and embryo elongation undoubtably were important in my experiment. Several treatments, notably the 17/20 and 20/20 treatments, produced enough dry matter (photosynthate) to support a large pod load. The transport of the photosynthate to the reproductive organs may

also have been affected. In a number of the lower yielding treatments, flowering appeared to be adequate. My experiment was not designed to determine which of the above physiological effects was present in each treatment. Lower photosynthate production, reduced photosynthate transport, and reduced flower production and efficiency are probably all important. Their relative importance undoubtably varies from treatment to treatment depending upon specific day and night temperatures and their interaction.

SUMMARY AND CONCLUSIONS

The peanut is affected by the temperature of its environment.
The length of phenological growth periods as controlled by develop-
mental rates is markedly affected as is plant growth. My research
was conducted on the Florunner variety of peanuts (Arachis hypogaea L.)
to delineate some of the effects of temperature on the peanut plant.
Several growth period variables were studied: 1. germination;
2. vegetative; 3. flowering; 4. filling; and 5. total period of
growth and development. Measurements were taken on a number of vege-
tative and reproductive portions of the plant. These were: 1. total
dry weight; 2. root dry weight; 3. stem dry weight; 4. leaf dry
weight; 5. total pod dry weight; 6. total pod number; 7. mature pod
dry weight; 8. mature pod number; 9. total reproductive dry weight.
The research was conducted at the Duke University Phytotron of the
Southeastern Plant Environment Laboratories located at Duke University,
Durham, N.C.

Day, night, and mean temperatures were found to influence pheno-
logic growth period length and the total length of growth through the
end of each of the developmental periods. The effect of temperature
varied depending on the growth period.

The germination and vegetative period lengths exhibited no
correlation to day temperature. These periods were negatively and
significantly correlated to night and mean temperature effects at

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P<.0001. The total length of development through the vegetative period was positively correlated to vegetative period length at P<.0001. The highly significant correlation indicates that no change in developmental effect of temperature occurred between the first two periods.

Flowering period length showed no correlation significance to day, night, or mean temperature when all temperature treatments were considered. A change in developmental effects occurred in the flowering period necessitating a division of the treatments into two groups. Upon separation into groups with mean temperatures of 20 C or higher or with mean temperature of 19 C or lower, significant correlation to mean temperature was obtained. The 19C or lower group was positively correlated at P=.0008. The 20 C or higher group was negatively correlated at P=.0046. Night temperature effects show no correlation for either group and day temperature effects were negatively significant at P=.0582 for the first group and positively significant at P=.1067 for the second. Before the division of treatments, the total developmental length through the flowering period did not have a significant correlation to day temperature while night and mean temperature effects were correlated negatively and significantly at about the 3% level. The data division produced positive and significant correlations for mean temperature effect (P=.0026 for the 19 C or lower group and P=.0024 for the 20 C or higher group). Day and night temperature effects were non-significantly correlated except for significance (negative correlation) at about the 3% level for treatments with 20 C or higher mean temperatures.

Significant correlations of 1.00 and 0.99 were obtained between the total length of development through flowering and the length of

the flowering period for the 20 C or higher group and the 19 C or
lower group, respectively. The correlation r-value was .93 before the
data division. The flowering period length of the low temperature
treatments was apparently controlled by vegetative growth factors
while the length of the warmer treatments was controlled by growth
and development of pod load.

The length of the filling period showed no significant correla-
tion to the three temperature groups prior to division of the treat-
ments. After the division, the mean temperature correlations became
highly significant in both groups at P=.0089 (negative correlation)
for the 20 C or higher group and P=.0028 (positive correlation) for
the 19 C or lower group. Day temperature effect was non-significant
and night temperature was only significant (positive correlation) at
P=.0271 in the 19 C or lower mean group. The correlation of the
length of the filling period to the total days of development through
filling had significant positive correlations at P=.0003 for both
groups after the division of data. The change in developmental trends
during the flowering period greatly affected the filling period. The
flowering period was included as part of the filling period length.

The total period of plant growth through final harvest lacked
strong correlation to the three temperature groups. However, mean
and night temperature effects had negative and significant correla-
tions at P=.0023 and P=.0090, respectively. The division of data made
little difference on the level of significance of the three temperature
group correlations.

Mainstem height, as an indicator of plant growth habit, had a
high r-value (.82) and significance (P=.0001) for mean temperature.

The r-values for day and night temperature groups were lower (.69 and .57, respectively) but day temperature nevertheless had high significance (P=.0033). Night temperature was correlated significantly at P=.0201.

Total plant dry weight, root dry weight, root dry weight percentage, stem dry weight, and stem dry weight percentage all had very high analysis of variance R^2 values (.93 or greater) at both harvests. The levels of significance for day, night, and day-night interaction were greater than .0001. Leaf dry weight and dry weight percentage had an R^2 value above .93 for the final harvest and .84 for the second harvest. The significance of night temperatures and day-night interaction was also high (P<.0001). Day temperature, however, was lower in significance at the second harvest with dry weight percentage only having significance at the 4% level. The final harvest significances were high although the value for leaf dry weight was slightly lower at .0032.

Total pod dry weight analysis of variance R^2 was higher than .94 for both harvests and the significance levels were greater than .0001 for both temperature groups and interaction. Mature pod dry weight, mature pod dry weight percentage, total pod number, mature pod number, and mature pod number percentage were significantly affected by temperature at levels greater than P=.0001 for night temperature and day-night temperature interaction at both harvests. An exception was mature pod dry weight percentage that had significance at exactly the 1% level for day-night interaction at the second harvest. The R^2 values were often variably lower (from .67 to .99) than the high values of the vegetative components. The lower values indicate more error and variability in the measurements of these factors.

Day temperature showed variable significance levels among the reproductive components studied. Mature pod dry weight had a second harvest significance that was slightly lower (P=.0019) than the high values of night temperature and day-night interaction. Mature pod dry weight percentage had a reduced day temperature significance close to the 1% level at the final harvest. Mature pod number had a slightly reduced significance of .0004 at the second harvest. Mature pod number percentage had no significance for day temperature at the final harvest while the second harvest showed high significance (P=.0001).

Reproductive dry weight percentage was greatly affected by day and night temperature and day-night temperature interaction (P<.0001). The R^2 was .96 to .99 for the two harvests.

Lower analysis of variance F-values and significance for day temperature indicate a reduced effect of day temperature on the growth and development of the Florunner variety. The reproductive components had the greatest reduction in significance. The amount of the reduction related to the shorter duration of the day temperature treatments (8 hours versus 16 hours for night temperature) is unknown.

The high R^2 values for all vegetative components indicates that most non-experimental variation was removed from the experiment in respect to these variables. In other words, experimental conditions were adequately controlled for all environmental growth factors. The high values also emphasize the large effect temperature has on the growth and development of the peanut plant.

Mature pod dry weight percentage of total pod dry weight indicated that the Florunner variety yields an almost constant value of 90% mature pods over a wide range of temperatures. The mature pod number

percentage did not remain constant. Data indicated that the Florunner variety exhibits thermoperiodicity where constant temperatures tend to retard plant growth and development. Thermoperiodicity was clearly seen in the 26/26 (day/night) treatment as a reduction in dry weights and pod numbers. However, this treatment had one of the highest partitioning levels to the pod component. Thermoperiodicity in the 20/20 constant temperature treatment was partially masked by low pod set and high total dry weight production. Both the 17/20 and 20/20 treatments had a unique growth pattern that was different from all other treatments.

A higher night than day temperature was advantageous to peanut yield. The 17/26 and 20/26 treatments increased pod set over one and one-half times that of any other treatment. The 17/20 treatment did not show such a large increase but did produce more than the constant temperature 20/20 treatment. Yield was not increased significantly due to a low solar radiation level during the filling periods of the 17/26 and 20/26 treatments.

The first two phenological growth periods increased in length as temperature decreased. Total length of development through the vegetative period was 31 days for the 32/26 and 26/26 treatments and 75 days for the 17/11 treatment. A fundamental change in developmental patterns occured in the flowering period. The 17/11 treatment bloomed for a similar length of time as the 32/26 treatment.

A high day or night temperature often counteracted the negative effect of corresponding low night or day temperatures on plant growth and development. The lack of detrimental effects of low day temperature upon growth and development at 26 C night temperature can possibly be

explained by inactivation of certain enzyme systems within the plant.
Phospho-glycolate production would be inhibited at the day temperatures
of 17 and 20 C. The inhibition would reduce photorespiration and may
account for the growth enhancement of lower day temperatures at 26 C
night temperature. The exact reasons await further research.

Overall, warm night temperatures (especially the 26 C night group
effect) appear better able to counteract the negative effects of a
corresponding low day temperature than warm day temperatures can
counteract the effects of cool night temperatures. The findings of
Hilliard and West (1970) (in work with Digitaria decumbens) may explain
the inability of day temperature to counteract low night temperatures.
They found that cool night temperatures slow or inhibit starch trans-
location out of chloroplasts and that the reduced translocation appears
to account for reduced photosynthesis and growth at low night temper-
atures. The "packing" of starch grains in the chloroplast prevent max-
imum photosynthesis from occuring. The peanut awaits further research
to assertain whether the poor growth at low night temperatures is
explainable in a similiar manner.

Temperature strongly affects the peanut plant. Like most crop
plants, temperature affects both growth and development of the peanut.
Unlike many crop plants, the effect is confounded by the unusual trait
of the peanut producing its seeds under the soil surface while beginning
its reproductive phase above ground. This unique complication makes
exacting research difficult and the delineation of specific temperature
effects complicated. Nevertheless, the effect of temperature on the
peanut is becoming understood. Exacting research conditions are needed
in order to exactly separate effects. It is felt that the controlled
conditions of my research were conducive to a better understanding of
temperature effects on Arachis hypogaea L.

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APPENDIX A

TABLES OF TREATMENT MEANS, NUMBER OF
PLANTS, AND MEAN SEPARATION BY DUNCAN'S MULTIPLE
RANGE TEST FOR DAY AND NIGHT TEMPERATURE GROUPS

Table A-1. Total dry weight treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for day temperature groups.

Night Tempera- ture (C)	Day Temperature (C)†															
	17				20				26				32			
	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01
	gm				gm				gm				gm			
						Second Harvest										
11	7.5	4	c	c	10.5	4	c	c	82.5	4	c	c	83.4	7	c	c
14	14.6	3	c	c	29.4	4	c	c	218.3	4	a	a	146.1	4	b	b
20	375.8	8	a	a	299.0	8	a	a	235.7	4	a	a	152.5	4	b	ab
26	175.2	4	b	b	181.1	4	b	b	140.3	3	b	b	180.8	4	a	a
						Final Harvest										
11	11.7	4	c	c	17.5	4	c	c	94.0	4	b	b	83.4	7	d	d
14	22.6	4	c	c	49.0	4	b	b	259.2	4	a	a	179.6	3	c	c
20	375.8	8	a	a	299.0	8	a	a	282.2	4	a	a	239.8	4	b	b
26	304.1	4	b	b	304.1	3	a	a	268.6	4	a	a	326.6	4	a	a

† Means with different letters are significantly different. Largest values designated by "a".

Table A-2. Total dry weight treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for night temperature groups.

Day Tempera- ture (C)	Night Temperature (C)[+]															
	11				14				20				26			
	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01
	gm				gm				gm				gm			
					Second Harvest											
17	7.5	4	b	b	14.6	3	c	c	375.8	8	a	a	175.2	4	a	a
20	10.5	4	b	b	29.4	4	c	c	299.0	8	b	b	181.1	4	a	a
26	82.5	4	a	a	218.3	4	a	a	235.7	4	c	c	140.3	3	b	a
32	83.4	7	a	a	146.1	4	b	b	152.5	4	d	d	180.8	4	a	a
					Final Harvest											
17	11.7	4	b	b	22.6	4	d	c	375.8	8	a	a	304.1	4	ab	a
20	17.5	4	b	b	49.0	4	c	c	299.0	8	b	b	304.1	3	ab	a
26	94.0	4	a	a	259.2	4	a	a	282.2	4	b	bc	268.6	4	b	a
32	83.4	7	a	a	179.6	3	b	b	239.8	4	c	c	326.6	4	a	a

[+] Means with different letters are significantly different. Largest values designated by "a".

Table A-3. Root dry weight treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for day temperature groups.

Night Tempera- ture (C)	Day Temperature (C)+																			
	17				20				26				32			
			alpha				alpha				alpha				alpha	
	Mean	N	.05	.01	Mean	N	.05	.01	Mean	N	.05	.01	Mean	N	.05	.01
	gm				gm				gm				gm			
					Second Harvest											
11	2.6	4	c	c	3.4	4	d	d	13.2	4	b	b	12.1	7	b	b
14	4.7	3	c	c	8.8	4	c	c	25.1	4	a	a	10.8	4	b	b
20	57.3	8	a	a	47.8	8	a	a	23.5	4	a	a	15.5	4	a	a
26	13.4	4	b	b	16.1	4	b	b	9.5	3	b	b	16.6	4	a	a
					Final Harvest											
11	4.1	4	d	c	5.5	4	c	c	16.7	4	c	b	12.1	7	b	b
14	7.6	4	c	c	12.2	4	b	b	31.5	4	a	a	15.4	3	ab	ab
20	57.3	8	a	a	47.8	8	a	a	20.0	4	b	b	13.5	4	ab	ab
26	15.6	4	b	b	14.5	3	b	a	12.2	4	d	c	16.9	4	a	a

+ Means with different letters are significantly different. Largest values designated by "a".

Table A-4. Root dry weight treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for night temperature groups.

Day Temperature (C)	Night Temperature (C)†															
	11				14				20				26			
	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01
	gm				gm				gm				gm			
							Second Harvest									
17	2.6	4	b	b	4.7	3	c	c	57.3	8	a	a	13.4	4	b	ab
20	3.4	4	b	b	8.8	4	b	b	47.8	8	b	b	16.1	4	ab	a
26	13.2	4	a	a	25.1	4	a	a	23.5	4	c	c	9.5	3	c	b
32	12.1	7	a	a	10.8	4	b	b	15.5	4	d	d	16.6	4	a	a
							Final Harvest									
17	4.1	4	c	c	7.6	4	c	c	57.3	8	a	a	15.6	4	a	ab
20	5.5	4	c	c	12.2	4	b	bc	47.8	8	b	b	14.5	3	ab	ab
26	16.7	4	a	a	31.5	4	a	a	20.0	4	c	c	12.2	4	b	b
32	12.1	7	b	b	15.4	3	b	b	13.5	4	d	d	16.9	4	a	a

† Means with different letters are significantly different. Largest values designated by "a".

Table A-5. Root dry weight percentage treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for day temperature groups.

Night Tempera- ture (C)	Day Temperature (C)[†]															
	17				20				26				32			
	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01
	gm				gm				gm				gm			
					Second Harvest											
11	35.0	4	a	a	32.7	4	a	a	16.1	4	a	a	14.6	7	a	a
14	32.2	3	a	a	30.5	4	a	a	11.5	4	b	b	7.4	4	c	b
20	15.3	8	b	b	16.0	8	b	b	9.9	4	b	b	10.2	4	b	b
26	7.7	4	c	c	8.9	4	c	c	6.9	3	c	c	9.1	4	bc	b
					Final Harvest											
11	35.1	4	a	a	31.1	4	a	a	17.8	4	a	a	14.6	7	a	a
14	33.5	4	a	a	24.8	4	a	b	12.2	4	b	b	8.5	3	b	b
20	15.3	8	b	b	16.0	8	b	b	7.0	4	c	c	5.6	4	c	b
26	5.2	4	c	c	4.8	3	c	d	4.5	4	d	d	5.2	4	c	b

† Means with different letters are significantly different. Largest values designated by "a".

Table A-6. Root dry weight percentage treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for night temperature groups.

Night Tempera-ture (C)	Night Temperature (C)†															
	11				14				20				26			
			alpha				alpha				alpha				alpha	
	Mean	N	.05	.01	Mean	N	.05	.01	Mean	N	.05	.01	Mean	N	.05	.01
	gm				gm				gm				gm			
					Second Harvest											
17	35.0	4	a	a	32.2	3	a	a	15.3	8	a	a	7.7	4	ab	a
20	32.7	4	a	a	30.5	4	a	a	16.0	8	a	a	8.9	4	a	a
26	16.1	4	b	b	11.5	4	b	b	9.9	4	b	b	6.9	3	b	a
32	14.6	7	b	b	7.4	4	b	b	10.2	4	b	b	9.1	4	a	a
					Final Harvest											
17	35.1	4	a	a	33.5	4	a	a	16.0	8	a	a	5.2	4	a	a
20	31.1	4	b	a	24.8	4	b	b	15.3	8	a	a	4.8	3	a	a
26	17.8	4	c	b	12.2	4	c	c	7.1	4	b	b	4.5	4	a	a
32	14.6	7	c	b	8.5	3	d	d	5.6	4	c	b	5.2	4	a	a

† Means with different letters are significantly different. Largest values designated by "a".

Table A-7. Stem dry weight treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for day temperature groups.

Night Tempera-	Day Temperature (C)†																		
	17				20				26				32			
ture (C)	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01
	gm				gm				gm				gm			
					Second Harvest											
11	2.6	4	c	c	3.7	4	c	c	35.8	4	c	c	30.3	7	c	b
14	5.4	3	c	c	10.5	4	c	c	102.9	4	a	a	45.4	4	b	a
20	182.3	8	a	a	145.8	8	a	a	60.2	4	b	a	46.5	4	b	a
26	47.8	4	b	b	48.6	4	b	b	39.3	3	c	bc	55.6	4	a	a
					Final Harvest											
11	4.2	4	c	c	5.9	4	c	c	41.0	4	c	b	30.3	7	c	c
14	8.2	4	c	c	19.3	4	c	c	128.0	4	a	a	52.0	3	b	b
20	182.3	8	a	a	145.8	8	a	a	51.5	4	b	b	44.9	4	b	b
26	78.7	4	b	b	61.1	3	b	b	49.5	4	bc	b	73.2	4	a	a

†Means with different letters are significantly different. Largest values designated by "a".

Table A-8. Stem dry weight treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for night temperature groups.

Day Temperature (C)	Night Temperature (C)[†]															
	11				14				20				26			
	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01
	gm				gm				gm				gm			
Second Harvest																
17	2.6	4	c	b	5.4	3	c	c	182.3	8	a	a	47.8	4	ab	a
20	3.7	4	c	b	10.5	4	c	c	145.8	8	b	b	48.6	4	ab	a
26	35.8	4	a	a	102.9	4	a	a	60.2	4	c	c	39.3	3	b	a
32	30.3	7	b	a	45.4	4	b	b	46.5	4	c	c	55.6	4	a	a
Final Harvest																
17	4.2	4	c	c	8.2	4	d	c	182.3	8	a	a	78.7	4	a	a
20	5.0	4	c	c	19.3	4	c	c	145.8	8	b	b	61.1	3	bc	ab
26	41.0	4	a	a	128.0	4	a	a	51.5	4	c	c	49.5	4	c	b
32	30.3	7	b	b	52.0	3	b	b	44.9	4	c	c	73.2	4	ab	a

[†] Means with different letters are significantly different. Largest values designated by "a".

Table A-9. Stem dry weight percentage treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for day temperature groups.

Night Tempera-ture (C)	Day Temperature (C)†															
	17				20				26				32			
			alpha				alpha				alpha				alpha	
	Mean	N	.05	.01	Mean	N	.05	.01	Mean	N	.05	.01	Mean	N	.05	.01
	%				%				%				%			
Second Harvest																
11	35.2	4	b	b	35.1	4	b	b	43.5	4	a	a	36.3	7	a	a
14	36.5	3	b	b	35.8	4	b	b	47.1	4	a	a	31.4	4	a	a
20	48.5	8	a	a	48.6	8	a	a	25.3	4	b	b	30.6	4	b	a
26	27.3	4	c	c	27.8	8	c	c	27.9	3	b	b	30.7	4	b	a
Final Harvest																
11	36.2	4	b	b	34.0	4	c	c	43.6	4	b	b	36.3	7	a	a
14	36.3	4	b	b	39.4	4	b	b	49.4	4	a	a	28.8	3	b	b
20	48.5	8	a	a	48.6	8	a	a	18.2	4	c	c	18.7	4	c	c
26	25.9	4	c	c	20.1	3	c	d	18.5	4	c	d	22.4	4	c	bc

† Means with different letters are significantly different. Largest values designated by "a".

Table A-10. Stem dry weight percentage treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for night temperature groups.

Day Tempera- ture (C)	Night Temperature (C)†															
	11				14				20				26			
	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01
	%				%				%				%			
					Second Harvest											
17	35.2	4	b	b	36.5	3	b	b	48.5	8	a	a	27.3	4	ab	a
20	35.1	4	b	b	35.8	4	b	b	48.6	8	a	a	26.8	4	b	a
26	43.5	4	a	a	47.1	4	a	a	25.3	4	c	b	27.9	3	ab	a
32	36.3	7	b	b	31.4	4	c	b	30.6	4	b	b	30.7	4	a	a
					Final Harvest											
17	36.2	4	b	b	36.3	4	c	b	48.5	8	a	a	25.9	4	a	a
20	34.0	4	b	b	39.4	4	b	b	48.6	8	a	a	20.1	3	c	bc
26	43.6	4	a	a	49.4	4	a	a	18.2	4	b	b	18.5	4	c	c
32	36.3	7	b	b	28.8	3	d	b	18.7	4	b	b	22.4	4	b	b

† Means with different letters are significantly different. Largest values designated by "a".

Table A-11. Leaf dry weight treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for day temperature groups.

Night Tempera- ture (C)	Day Temperature (C)[†]															
	17				20				26				32			
	Mean	N	.05 alpha	.01	Mean	N	.05 alpha	.01	Mean	N	.05 alpha	.01	Mean	N	.05 alpha	.01
	gm				gm				gm				gm			
					Second Harvest											
11	2.3	4	c	c	3.4	4	c	c	32.9	4	c	c	30.9	7	c	c
14	4.6	3	c	c	10.0	4	c	c	76.4	4	a	a	37.9	4	b	b
20	119.1	8	a	a	89.3	8	a	a	47.9	4	b	b	39.3	4	b	ab
26	49.6	4	b	b	48.8	4	b	b	38.4	3	c	bc	45.2	4	a	a
					Final Harvest											
11	3.4	4	c	c	6.0	4	c	c	35.9	4	c	b	30.9	7	c	c
14	6.9	4	c	c	16.2	4	c	c	83.7	4	a	a	43.1	3	b	b
20	119.1	8	a	a	89.3	8	a	a	46.9	4	b	b	40.5	4	b	b
26	57.3	4	b	b	57.7	3	b	b	46.7	4	b	b	65.6	4	a	a

† Means with different letters are significantly different. Largest values designated by "a".

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Table A-12. Leaf dry weight treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for night temperature groups.

Day Tempera- ture (C)	Night Temperature (C)†															
	11				14				20				26			
	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01
	gm				gm				gm				gm			
					Second Harvest											
17	2.3	4	b	b	4.6	3	d	c	119.1	8	a	a	49.6	4	a	a
20	3.4	4	b	b	10.0	4	c	c	89.3	8	b	b	48.8	4	a	a
26	32.9	4	a	a	76.4	4	a	a	47.9	4	c	c	38.4	3	b	b
32	30.9	7	a	a	37.9	4	b	b	39.3	4	c	c	45.2	4	ab	a
					Final Harvest											
17	3.4	4	c	b	6.9	4	d	c	119.1	8	a	a	57.3	4	ab	a
20	6.0	4	c	b	16.2	4	c	c	89.3	8	b	b	57.7	4	ab	a
26	35.9	4	a	a	83.7	4	a	a	46.9	4	c	c	46.7	4	b	a
32	30.9	7	b	a	43.1	3	b	b	40.5	4	c	c	65.6	4	a	a

† Means with different letters are significantly different. Largest values designated by "a".

Table A-13. Leaf dry weight percentage treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for day temperature groups.

Night Tempera-ture (C)	Day Temperature (C) [†]															
	17				20				26				32			
	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01
	%				%				%				%			
Second Harvest																
11	29.8	4	ab	a	32.2	4	a	ab	39.9	4	a	a	37.3	7	a	a
14	31.3	3	ab	a	33.8	4	a	a	35.0	4	b	b	26.2	4	b	b
20	31.7	8	a	a	29.7	8	ab	ab	20.2	4	d	d	25.8	4	b	b
26	28.3	4	b	a	26.9	4	b	b	27.4	3	c	c	25.1	4	b	b
Final Harvest																
11	28.7	4	b	a	34.3	4	a	a	38.1	4	a	a	37.3	7	a	a
14	30.2	4	ab	a	33.2	4	ab	a	32.3	4	b	b	23.9	3	b	b
20	31.7	8	a	a	29.7	8	b	a	16.6	4	c	c	16.9	4	c	c
26	18.7	4	c	b	19.0	3	c	b	17.2	4	c	c	20.1	4	c	bc

[†] Means with different letters are significantly different. Largest values designated by "a".

Table A-14. Leaf dry weight percentage treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for night temperature groups.

Day Temperature (C)	Night Temperature (C)[+]															
	11				14				20				26			
	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01	Mean	N	alpha .05	alpha .01
	%				%				%				%			
Second Harvest																
17	29.8	4	b	b	31.3	3	a	ab	31.7	8	a	a	28.3	4	a	a
20	32.2	4	b	b	33.8	4	a	a	29.7	8	a	ab	26.9	4	ab	a
26	39.9	4	a	a	35.0	4	a	a	20.2	4	c	c	27.4	3	ab	a
32	37.3	7	a	a	26.2	4	b	b	25.8	4	b	b	25.1	4	b	a
Final Harvest																
17	28.7	4	b	b	30.2	4	b	b	31.7	8	a	a	18.7	4	a	a
20	34.3	4	a	a	33.2	4	a	a	29.7	8	a	a	19.0	3	a	a
26	38.1	4	a	a	32.3	4	a	ab	16.6	4	b	b	17.2	4	a	a
32	37.3	7	a	a	23.9	3	c	c	16.9	4	b	b	20.1	4	a	a

[+] Means with different letters are significantly different. Largest values designated by "a".

Table A-15. Total pod dry weight treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for day temperature groups.

Night Tempera- ture (C)	Day Temperature (C)†															
	17				20				26				32			
			alpha				alpha				alpha				alpha	
	Mean	N	.05	.01	Mean	N	.05	.01	Mean	N	.05	.01	Mean	N	.05	.01
	gm				gm				gm				gm			
					Second Harvest											
11	0.0	4	c	c	0.0	4	c	c	0.4	4	c	c	8.6	7	b	b
14	0.0	3	c	c	0.0	4	c	c	11.8	4	c	c	47.1	4	a	a
20	12.8	8	b	b	10.3	8	b	b	88.6	4	a	a	41.3	4	a	a
26	51.6	4	a	a	55.8	4	a	a	44.3	3	b	b	52.3	4	a	a
					Final Harvest											
11	0.0	4	c	c	0.0	4	c	c	0.1	4	c	b	8.6	7	d	d
14	0.0	4	c	c	0.1	4	c	c	12.4	4	b	b	59.0	3	c	c
20	12.8	8	b	b	10.3	8	b	b	154.8	4	a	a	131.4	4	b	b
26	130.3	4	a	a	159.5	3	a	a	151.0	4	a	a	158.0	4	a	a

† Means with different letters are significantly different. Largest values designated by "a".

Table A-16. Total pod dry weight treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for night temperature groups.

Day Tempera-ture (C)	Night Temperature (C)†															
	11				14				20				26			
	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01
	gm				gm				gm				gm			
					Second Harvest											
17	0.0	4	b	b	0.0	3	b	b	12.8	8	c	c	51.6	4	a	a
20	0.0	4	b	b	0.0	4	b	b	10.3	8	c	c	55.8	4	a	a
26	0.4	4	b	b	11.8	4	b	b	88.6	4	a	a	44.3	3	a	a
32	8.6	7	a	a	47.1	4	a	a	41.3	4	b	b	52.3	4	a	a
					Final Harvest											
17	0.0	4	b	b	0.0	4	c	c	12.8	8	c	c	130.3	4	b	b
20	0.0	4	b	b	0.1	4	c	c	10.3	3	c	c	159.5	3	a	a
26	0.1	4	b	b	12.4	4	b	b	154.8	4	b	b	151.0	4	a	ab
32	8.6	7	a	a	59.0	3	a	a	131.4	4	a	a	158.0	4	a	a

† Means with different letters are significantly different. Largest values designated by "a".

Table A-17. Mature pod dry weight treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for day temperature groups.

Night Tempera-ture (C)	Day Temperature (C)[†]															
	17				20				26				32			
	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01
	gm				gm				gm				gm			
	Second Harvest															
11	0.0	4	b	b	0.0	4	b	b	0.0	4	b	b	1.3	7	b	b
14	0.0	3	b	b	0.0	4	b	b	1.1	4	b	b	15.6	4	a	a
20	12.4	8	a	a	8.7	8	a	a	27.5	4	a	a	2.7	4	b	b
26	7.9	4	ab	ab	7.3	4	a	ab	6.7	3	b	b	22.7	4	a	a
	Final Harvest															
11	0.0	4	c	b	0.0	4	c	b	0.0	4	c	b	1.3	7	d	d
14	0.0	4	c	b	0.0	4	c	b	7.3	4	c	b	46.7	3	c	c
20	12.4	8	b	b	8.7	8	b	b	139.7	4	a	a	114.3	4	b	b
26	112.9	4	a	a	148.5	3	a	a	125.0	4	b	a	144.3	4	a	a

† Means with different letters are significantly different. Largest values designated by "a".

Table A-18. Mature pod dry weight treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for night temperature groups.

Day Tempera-ture (C)	Night Temperature (C) †															
	11				14				20				26			
	Mean	N	.05	.01	Mean	N	.05	.01	Mean	N	.05	.01	Mean	N	.05	.01
	gm		alpha		gm		alpha		gm		alpha		gm		alpha	
Second Harvest																
17	0.0	4	a	a	0.0	3	b	b	12.4	8	b	b	7.9	4	b	b
20	0.0	4	a	a	0.0	4	b	b	8.7	8	bc	b	7.3	4	b	b
26	0.0	4	a	a	1.1	4	b	b	27.5	4	a	a	6.7	3	b	b
32	1.3	7	a	a	15.6	4	a	a	2.7	4	c	b	22.7	4	a	a
Final Harvest																
17	0.0	4	a	a	0.0	4	c	c	12.4	8	c	c	112.9	4	b	b
20	0.0	4	a	a	0.0	4	c	c	8.7	8	c	c	148.5	3	a	a
26	0.0	4	a	a	7.3	4	b	b	139.7	4	a	a	125.0	4	b	ab
32	1.3	7	a	a	46.7	3	a	a	114.3	4	b	b	144.3	4	a	a

† Means with different letters are significantly different. Largest values designated by "a".

Table A-19. Mature pod dry weight percentage treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for day temperature groups.

Night Tempera-	Day Temperature (C)†															
	17				20				26				32			
			alpha				alpha				alpha				alpha	
ture (C)	Mean %	N	.05	.01	Mean %	N	.05	.01	Mean %	N	.05	.01	Mean %	N	.05	.01
							Second Harvest									
11	--	-	-	-	--	-	-	-	0.0	4	b	b	20.7	7	a	a
14	--	-	-	-	--	-	-	-	6.7	4	b	b	29.4	4	a	a
20	93.0	8	a	a	86.7	8	a	a	30.9	4	a	a	6.7	4	a	a
26	15.6	4	b	b	13.4	4	b	b	12.9	3	b	ab	43.4	4	a	a
							Final Harvest									
11	--	-	-	-	--	-	-	-	0.0	2	c	c	20.7	7	b	b
14	--	-	-	-	--	-	-	-	56.9	4	b	b	79.3	3	a	a
20	93.0	8	a	a	86.7	8	a	a	90.1	4	a	a	86.8	4	a	a
26	86.6	4	a	a	93.1	3	a	a	83.1	4	a	ab	91.3	4	a	a

†Means with different letters are significantly different. Largest values designated by "a".

Table A-20. Mature pod dry weight percentage treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for night temperature groups.

Day Tempera-ture (C)	Night Temperature (C)[†]															
	11				14				20				26			
	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01
	%				%				%				%			
Second Harvest																
17	--	-	-	-	--	-	-	-	93.0	8	a	a	15.6	4	b	b
20	--	-	-	-	--	-	-	-	86.7	8	a	a	13.4	4	b	b
26	0.0	4	a	a	6.7	4	a	a	30.9	4	b	b	12.9	3	b	b
32	20.7	7	a	a	29.4	4	a	a	6.7	4	c	c	43.4	4	a	a
Final Harvest																
17	--	-	-	-	--	-	-	-	93.0	8	a	a	86.6	4	ab	a
20	--	-	-	-	0.0	1	b	b	86.1	8	a	a	93.1	3	a	a
26	0.0	2	a	a	56.9	4	a	ab	90.1	4	a	a	83.1	4	b	a
32	20.7	7	a	a	79.3	3	a	a	86.8	4	a	a	91.3	4	a	a

† Means with different letters are significantly different. Largest values designated by "a".

Table A-21. Total pod number treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for day temperature groups.

Night Tempera-ture (C)	Day Temperature (C)†															
	17				20				26				32			
	Mean	N	.05	.01	Mean	N	.05	.01	Mean	N	.05	.01	Mean	N	.05	.01
	no.		alpha		no.		alpha		no.		alpha		no.		alpha	
							Second Harvest									
11	0.0	4	c	b	0.0	4	b	b	2.5	4	b	b	24.9	7	c	c
14	0.0	3	c	b	0.0	4	b	b	31.3	4	b	b	143.5	4	b	b
20	13.4	8	b	b	10.8	8	b	b	228.8	4	a	a	164.8	4	b	b
26	354.5	4	a	a	282.5	4	a	a	242.3	3	a	a	223.5	4	a	a
							Final Harvest									
11	0.0	4	b	c	0.0	4	b	c	0.5	4	c	c	24.9	7	c	c
14	0.0	4	b	c	0.5	4	b	c	30.3	4	c	c	201.3	3	b	b
20	13.4	8	b	b	10.8	8	b	b	235.5	4	b	b	205.3	4	b	b
26	487.8	4	a	a	403.3	3	a	a	290.8	4	a	a	261.8	4	a	a

†Means with different letters are significantly different. Largest values designated by "a".

Table A-22. Total pod number treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for night temperature groups.

Day Tempera-	Night Temperature (C)[†]															
	11				14				20				26			
			alpha				alpha				alpha				alpha	
ture (C)	Mean	N	.05	.01	Mean	N	.05	.01	Mean	N	.05	.01	Mean	N	.05	.01
	no.				no.				no.				no.			
							Second Harvest									
17	0.0	4	b	b	0.0	3	c	b	10.8	8	c	c	354.5	4	a	b
20	0.0	4	b	b	0.0	4	c	b	13.4	8	c	c	282.5	4	b	b
26	2.5	4	b	b	31.3	4	b	b	228.8	4	a	a	242.3	3	bc	b
32	24.9	7	a	a	143.5	4	a	a	164.8	4	b	b	223.5	4	c	a
							Final Harvest									
17	0.0	4	b	b	0.0	4	c	b	13.4	8	c	c	487.8	4	a	a
20	0.0	4	b	b	0.5	4	c	b	10.8	8	c	c	403.3	3	b	a
26	0.5	4	b	b	30.3	4	b	b	235.5	4	a	a	290.8	4	c	b
32	24.9	7	a	a	201.3	3	a	a	205.3	4	b	b	261.8	4	c	b

† Means with different letters are significantly different. Largest values designated by "a".

Table A-23. Mature pod number treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for day temperature groups.

Night Tempera-ture (C)	Day Temperature (C)+															
	17				20				26				32			
	Mean	N	alpha		Mean	N	alpha		Mean	N	alpha		Mean	N	alpha	
			.05	.01			.05	.01			.05	.01			.05	.01
	no.				no.				no.				no.			
						Second Harvest										
11	0.0	4	b	b	0.0	4	b	b	0.0	4	b	b	2.7	7	b	b
14	0.0	3	b	b	0.0	4	b	b	1.3	4	b	b	17.0	4	a	ab
20	11.5	8	a	a	7.1	8	a	a	21.3	4	a	a	3.0	4	b	b
26	7.0	4	ab	ab	6.0	4	a	ab	6.0	3	b	b	22.3	4	a	a
						Final Harvest										
11	0.0	4	c	c	0.0	4	c	b	0.0	4	c	c	2.7	7	d	d
14	0.0	4	c	c	0.0	4	c	b	9.8	4	c	c	69.0	3	c	c
20	11.5	8	b	b	7.1	8	b	b	75.0	4	a	a	90.8	4	b	b
26	80.8	4	a	a	97.7	3	a	a	121.5	4	b	b	124.3	4	a	a

+ Means with different letters are significantly different. Largest values designated by "a".

Table A-24. Mature pod number treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for night temperature groups.

Day Tempera-ture (C)	Night Temperature (C) †															
	11				14				20				26			
	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01
	no.				no.				no.				no.			
					Second Harvest											
17	0.0	4	a	a	0.0	3	b	b	11.5	8	b	ab	7.0	4	b	b
20	0.0	4	a	a	0.0	4	b	b	7.1	8	bc	b	6.0	4	b	b
26	0.0	4	a	a	1.3	4	b	b	21.3	4	a	a	6.0	3	b	b
32	2.7	7	a	a	17.0	4	a	a	3.0	4	c	b	22.3	4	a	a
					Final Harvest											
17	0.0	4	a	a	0.0	4	c	c	11.5	8	c	c	80.8	4	c	c
20	0.0	4	a	a	0.0	4	c	c	7.1	8	c	c	97.7	3	b	b
26	0.0	4	a	a	9.8	4	b	b	121.5	4	a	a	75.0	4	c	c
32	2.7	7	a	a	69.0	3	a	a	90.8	4	b	b	124.3	4	a	a

† Means with different letters are significantly different. Largest values designated by "a".

Table A-25. Mature pod number percentage treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for day temperature groups.

Night Tempera- ture (C)	Day Temperature (C) [†]															
	17				20				26				32			
	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01
	%				%				%				%			
Second Harvest																
11	--	--	--	--	--	--	--	--	0.0	4	b	b	13.5	7	a	a
14	--	--	--	--	--	--	--	--	2.8	4	b	ab	10.9	4	a	a
20	81.5	8	a	a	72.2	8	a	a	9.5	4	a	a	1.8	4	a	a
26	2.0	4	b	b	2.1	4	b	b	2.3	3	b	ab	10.2	4	a	a
Final Harvest																
11	--	--	--	--	0.0	1	--	--	0.0	2	c	c	13.5	7	b	b
14	--	--	--	--	0.0	1	b	b	32.4	4	b	ab	34.9	3	ab	ab
20	81.5	8	a	a	72.2	8	a	a	52.0	4	a	a	44.4	4	a	a
26	16.7	4	b	b	24.5	3	b	b	26.0	4	b	bc	47.6	4	a	a

[†] Means with different letters are significantly different. Largest values designated by "a".

Table A-26. Mature pod number percentage treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for night temperature groups.

Day Tempera-	Night Temperature (C)†															
	11		alpha		14		alpha		20		alpha		26		alpha	
ture (C)	Mean	N	.05	.01	Mean	N	.05	.01	Mean	N	.05	.01	Mean	N	.05	.01
	%				%				%				%			
					Second Harvest											
17	--	-	-	-	--	-	-	-	81.5	8	a	a	2.0	4	b	b
20	--	-	-	-	--	-	-	-	72.2	8	a	a	2.1	4	b	b
26	0.0	4	a	a	2.8	4	a	a	9.5	4	b	b	2.3	3	b	b
32	13.5	7	a	a	10.9	4	a	a	1.8	4	b	b	10.2	4	a	a
					Final Harvest											
17	--	-	-	-	0.0	1	a	a	81.5	8	a	a	16.7	4	c	c
20	--	-	-	-	--	-	a	a	72.2	8	a	ab	24.5	3	b	bc
26	0.0	2	a	a	32.4	4	a	a	52.0	4	b	bc	26.0	4	b	b
32	13.5	7	a	a	34.9	3	a	a	44.4	4	b	c	47.6	4	a	a

†Means with different letters are significantly different. Largest values designated by "a".

Table A-27. Reproductive dry weight percentage treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for day temperature groups.

Night Tempera-	Day Temperature (C)†															
ture (C)	17				20				26				32			
	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01
	%				%				%				%			
Second Harvest																
11	0.0	4	c	b	0.0	4	c	b	0.6	4	b	b	10.6	7	b	b
14	0.0	3	c	b	0.0	4	c	b	6.2	4	b	b	35.0	4	a	a
20	3.6	8	b	b	3.8	8	b	b	44.5	4	a	a	33.5	4	a	a
26	36.7	4	a	a	37.6	4	a	a	37.7	3	a	a	35.0	4	a	a
Final Harvest																
11	0.0	4	c	c	0.0	4	c	b	0.1	4	c	c	10.6	7	c	c
14	0.0	4	c	c	0.3	4	c	b	5.5	4	b	b	36.7	3	b	b
20	3.6	8	b	b	3.8	8	b	b	58.1	4	a	a	58.8	4	a	a
26	47.7	4	a	a	56.2	3	a	a	59.8	4	a	a	52.3	4	a	a

† Means with different letters are significantly different. Largest values designated by "a".

Table A-28. Reproductive dry weight percentage treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for night temperature groups.

Day Tempera-ture (C)	Night Temperature (C)†															
	11				14				20				26			
	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01	Mean	N	alpha .05	.01
	%				%				%				%			
					Second Harvest											
17	0.0	4	b	b	0.0	3	c	b	3.6	8	c	c	36.7	4	a	a
20	0.0	4	b	b	0.0	4	c	b	3.8	8	c	c	37.6	4	a	a
26	0.6	4	b	b	6.2	4	b	b	44.5	4	a	a	37.7	3	a	a
32	10.6	7	a	a	35.0	4	a	a	33.5	4	b	b	35.0	4	a	a
					Final Harvest											
17	0.0	4	b	b	0.0	4	c	c	3.6	8	b	b	47.7	4	d	c
20	0.0	4	b	b	0.3	4	c	c	3.8	8	b	b	56.2	3	b	ab
26	0.1	4	b	b	5.5	4	b	b	58.1	4	a	a	59.8	4	a	a
32	10.6	7	a	a	36.7	3	a	a	58.8	4	a	a	52.3	4	c	b

†Means with different letters are significantly different. Largest values designated by "a".

APPENDIX B

TABLES OF TREATMENT MEANS, NUMBER OF PLANTS,
COEFFICIENT OF VARIABILITY, AND MEAN SEPARATION
BY DUNCAN'S MULTIPLE RANGE TEST FOR ALL TREATMENTS

Table B-1. Total dry weight and root dry weight treatment means, number of plants, coefficient of variability, and mean separation by Duncan's Multiple Range Test for all treatments.

Temp. Treat.	Second Harvest[†]					Final Harvest[†]				
	Mean	N	alpha .05	.01	C.V.	Mean	N	alpha .05	.01	C.V.
Total Dry Weight (gm)										
17-20	375.8	8	a	a	4.8	375.8	8	a	a	4.8
32-26	180.8	4	d	d	9.1	326.6	4	b	b	4.6
20-26	181.1	4	d	d	4.4	304.1	3	bc	bc	4.9
17-26	175.2	4	d	de	10.3	304.1	4	bc	bc	12.3
20-20	299.0	4	b	b	8.7	299.0	8	c	bc	8.7
26-20	235.7	4	c	c	7.6	282.2	4	cd	cd	7.1
26-26	140.3	3	e	f	15.0	268.6	4	d	cde	21.4
26-14	218.3	4	c	c	1.1	259.2	4	de	de	4.9
32-20	152.5	4	e	def	7.0	239.8	4	e	e	6.7
32-14	146.1	4	e	ef	15.9	179.6	3	f	f	15.8
26-11	82.5	4	f	g	4.4	94.0	4	g	g	8.6
32-11	83.4	7	f	g	14.3	83.4	7	g	g	14.3
20-14	29.4	4	g	h	16.9	49.0	4	h	h	13.8
17-14	14.6	3	g	h	13.0	22.6	4	i	h	13.0
20-11	10.5	4	g	h	11.6	17.5	4	i	h	11.4
17-11	7.5	4	g	h	6.3	11.7	4	i	h	17.5
Root Dry Weight (gm)										
17-20	57.3	8	a	a	5.1	57.3	8	a	a	5.1
20-20	47.8	8	b	b	6.1	47.8	8	b	b	6.1
26-14	25.1	4	c	c	8.4	31.5	4	c	c	5.8
26-20	23.5	4	c	c	17.0	20.0	4	d	d	13.6
32-26	16.6	4	d	d	15.7	16.9	4	de	de	3.5
26-11	13.2	4	de	def	9.9	16.7	4	de	de	11.0
17-26	13.4	4	de	def	8.3	15.6	4	ef	def	16.9
32-14	10.8	4	efg	fg	13.0	15.4	3	efg	def	27.7
20-26	16.1	4	d	d	14.8	14.5	3	efg	ef	10.9
32-20	15.5	4	d	de	8.8	13.5	4	efg	ef	16.2
20-14	8.8	4	g	gh	12.1	12.2	4	efg	ef	17.1
26-26	9.5	3	fg	fg	2.7	12.2	4	fg	ef	13.2
32-11	12.1	7	ef	efg	12.9	12.1	7	g	ef	12.9
17-14	4.7	3	h	hi	13.2	7.6	4	h	g	13.4
20-11	3.4	4	h	i	11.8	5.5	4	hi	g	21.0
17-11	2.6	4	h	i	7.0	4.1	4	i	g	17.3

[†]Treatments with different letters are significantly different. Largest values designated by "a".

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Table B-2. Root dry weight percentage and stem dry weight treatment
means, number of plants, coefficient of variability, and
mean separation by Duncan's Multiple Range Test for all
treatments.

| Temp. | Second Harvest [†] | | | | Final Harvest [†] | | | |
| | Mean | N | .05 alpha | .01 | C.V. | Mean | N | .05 alpha | .01 | C.V. |
Treat.										
				Root Dry Weight Percentage (%)						
17-11	35.0	4	a	a	12.3	35.1	4	a	a	5.2
17-14	32.2	3	ab	ab	8.0	33.5	4	a	ab	6.8
20-11	32.7	4	ab	ab	6.8	31.1	4	b	b	10.5
20-14	30.5	4	b	b	15.8	24.8	4	c	c	4.0
26-11	16.1	4	c	c	9.3	17.8	4	d	d	14.7
20-20	16.0	8	c	c	4.1	16.0	8	e	de	4.1
17-20	15.3	8	c	c	6.1	15.3	8	e	e	6.1
32-11	14.6	7	c	cd	14.0	14.6	7	e	ef	14.0
26-14	11.5	4	d	de	7.9	12.2	4	f	f	3.9
32-14	7.4	4	e	ef	8.8	8.5	3	g	g	11.4
26-20	9.9	4	de	ef	11.4	7.1	4	gh	gh	10.0
32-20	10.2	4	de	ef	5.0	5.6	4	hi	gh	9.9
17-26	7.7	4	e	ef	13.3	5.2	4	hi	h	23.5
32-26	9.1	4	de	ef	7.0	5.2	4	hi	h	4.6
20-26	8.9	4	de	ef	13.6	4.8	3	hi	h	9.6
26-26	6.9	3	e	f	17.0	4.5	4	i	h	4.5
				Stem Dry Weight (gm)						
17-20	182.3	8	a	a	6.3	182.3	8	a	a	6.3
20-20	145.8	8	b	b	13.1	145.8	8	b	b	13.1
26-14	102.9	4	c	c	4.4	128.0	4	c	c	6.5
17-26	47.8	4	de	de	11.5	78.7	4	d	d	16.1
32-26	55.6	4	d	d	13.1	73.2	4	de	d	5.4
20-26	48.6	4	de	de	12.5	61.1	3	ef	de	7.7
32-14	45.4	4	de	def	8.9	52.0	3	fg	e	22.4
26-20	60.2	4	d	d	25.0	51.5	4	fg	e	12.0
26-26	39.3	3	ef	def	20.6	49.5	4	fg	e	5.9
32-20	46.5	4	de	def	5.7	44.9	4	g	ef	9.5
26-11	35.8	4	ef	ef	6.6	41.0	4	gh	ef	10.8
32-11	30.3	7	f	f	17.8	30.3	7	hi	fg	17.8
20-14	10.5	4	g	g	17.8	19.3	4	ij	gh	13.7
17-14	5.4	3	g	g	17.9	8.2	4	jk	h	10.6
20-11	3.7	4	g	g	13.9	5.9	4	jk	h	7.4
17-11	2.6	4	g	g	11.2	4.2	4	k	h	17.6

[†] Treatments with different letters are significantly different.
Largest values designated by "a".

Table B-3. Stem dry weight percentage and leaf dry weight treatment
means, number of plants, coefficient of variability, and
mean separation by Duncan's Multiple Range Test for all
treatments.

Temp.	Second Harvest[†]					Final Harvest[†]				
Treat.	Mean	N	alpha		C.V.	Mean	N	alpha		C.V.
			.05	.01				.05	.01	

Temp. Treat.	Mean	N	.05	.01	C.V.	Mean	N	.05	.01	C.V.
Stem Dry Weight Percentage (%)										
26-14	47.1	4	a	ab	4.5	49.4	4	a	a	2.8
20-20	48.6	8	a	a	4.9	48.6	8	a	a	4.9
17-20	48.6	8	a	a	4.3	48.5	8	a	a	4.3
26-11	43.5	4	b	b	3.4	43.6	4	b	b	3.6
20-14	35.8	4	c	cd	3.9	39.4	4	c	c	2.6
32-11	36.3	7	c	c	11.2	36.3	7	d	cd	11.2
17-14	36.5	3	c	c	6.4	36.3	4	d	cd	3.3
17-11	35.2	4	cd	cd	5.1	36.2	4	d	cd	1.2
20-11	35.1	4	cd	cd	4.8	34.0	4	d	d	4.7
32-14	31.4	4	de	cde	9.6	28.8	3	e	e	6.6
17-26	27.3	4	fg	ef	6.1	25.9	4	e	ef	8.7
32-26	30.7	4	ef	cde	5.7	22.4	4	f	fg	2.1
20-26	26.8	4	fg	ef	8.3	20.1	3	fg	gh	2.9
32-20	30.6	4	ef	def	4.2	18.7	4	g	gh	4.0
26-26	27.9	3	efg	ef	10.6	18.5	4	g	gh	4.3
26-20	25.3	4	g	f	18.3	18.2	4	g	h	5.2
Leaf Dry Weight (gm)										
17-20	119.1	8	a	a	8.7	119.1	8	a	a	8.7
20-20	89.3	8	b	b	18.1	89.3	8	b	b	18.1
26-14	76.4	4	c	c	4.2	83.7	4	b	b	4.2
32-26	45.2	4	d	de	4.2	65.6	4	c	c	4.7
20-26	48.8	4	d	d	9.6	57.7	3	cd	cd	12.7
17-26	49.6	4	d	d	10.7	57.3	4	cd	cd	23.0
26-20	47.9	4	d	de	18.0	46.9	4	de	de	4.6
26-26	38.4	3	de	def	13.8	46.7	4	de	de	21.8
32-14	37.9	4	de	def	8.9	43.1	3	def	def	18.8
32-20	39.3	4	de	def	4.7	40.5	4	ef	def	7.1
26-11	32.9	4	e	ef	3.9	35.9	4	ef	ef	11.6
32-11	30.9	7	e	f	12.8	30.9	7	f	f	12.8
20-14	10.0	4	f	g	26.0	16.2	4	g	g	10.1
17-14	4.6	3	f	g	10.9	6.9	4	gh	g	18.1
20-11	3.4	4	f	g	11.9	6.0	4	gh	g	6.8
17-11	2.3	4	f	g	15.1	3.4	4	h	g	19.5

[†] Treatments with different letters are significantly different.
Largest values designated by "a".

Table B-4. Leaf dry weight percentage and total pod dry weight treatment
means, number of plants, coefficient of variability, and mean
separation by Duncan's Multiple Range Test for all treatments.

Temp.	Second Harvest[†]				Final Harvest[†]				
			alpha					alpha		
Treat.	Mean	N	.05	.01	C.V.	Mean	N	.05	.01	C.V.
	Leaf Dry Weight Percentage (%)									
26-11	39.9	4	a	a	1.5	38.1	4	a	a	4.1
32-11	37.3	7	a	ab	14.0	37.3	7	a	a	8.6
20-11	32.2	4	cde	cde	3.5	34.3	4	b	ab	6.0
20-14	33.8	4	cd	bcd	12.5	33.2	4	bc	bc	4.2
26-14	35.0	4	bc	bc	3.3	32.3	4	bcd	bc	4.2
17-20	31.7	8	de	cde	5.9	31.7	8	bcd	bc	5.9
17-14	31.3	3	def	cdef	3.9	30.2	4	cde	bc	6.5
20-20	29.7	8	efg	defg	4.1	29.7	8	ed	c	11.9
17-11	29.8	4	efg	defg	9.1	28.7	4	e	c	7.0
32-14	26.2	4	gh	fg	8.8	23.9	3	f	d	6.8
32-26	25.1	4	h	g	9.1	20.1	4	g	de	3.1
20-26	26.9	4	gh	fg	5.3	19.0	3	g	de	11.4
17-26	28.3	4	fgh	efg	3.2	18.7	4	g	e	12.1
26-26	27.4	3	fgh	efg	5.0	17.2	4	g	e	14.0
32-20	25.8	4	h	fg	3.8	16.9	4	g	e	1.0
26-20	20.2	4	i	h	10.9	16.6	4	g	e	3.1
	Total Pod Dry Weight (gm)									
20-26	55.8	4	b	b	10.2	159.5	3	a	a	5.5
32-26	52.3	4	bc	b	10.4	158.0	4	a	a	3.7
26-20	88.9	4	a	a	12.9	154.8	4	a	a	7.4
26-26	44.3	3	bc	b	23.8	151.0	4	a	a	6.9
32-20	41.3	4	c	b	15.4	131.4	4	b	b	5.4
17-26	51.6	4	bc	b	17.5	130.3	4	b	b	12.4
32-14	47.1	4	bc	b	30.2	59.0	3	c	c	6.9
17-20	12.8	8	d	c	64.9	12.8	8	d	d	65.0
26-14	11.8	4	d	c	35.6	12.4	4	d	d	25.2
20-20	10.3	8	d	c	65.2	10.3	8	d	d	65.2
32-11	8.6	7	de	c	78.9	8.6	7	de	d	78.9
20-14	0.0	4	e	c	--	0.1	4	e	d	200.0
26-11	0.4	4	e	c	61.4	0.1	4	e	d	166.4
17-14	0.0	3	e	c	--	0.0	4	e	d	--
20-11	0.0	4	e	c	--	0.0	4	e	d	--
17-11	0.0	4	e	c	--	0.0	4	e	d	--

[†]Treatments with different letters are significantly different.
Largest values designated by "a".

Table B-5. Mature pod dry weight and mature pod dry weight percentage
treatment means, number of plants, coefficient of variability,
and mean separation by Duncan's Multiple Range Test for
all treatments.

Temp. Treat.	Second Harvest[†]					Final Harvest[†]				
	Mean	N	alpha .05	.01	C.V.	Mean	N	alpha .05	.01	C.V.
Mature Pod Dry Weight (gm)										
20-26	7.3	4	cde	cde	33.2	148.5	3	a	a	7.4
32-26	22.7	4	ab	ab	7.9	144.3	4	a	a	4.7
26-20	27.5	4	a	a	28.0	139.7	4	a	a	10.9
26-26	6.7	3	cde	cde	121.0	125.0	4	b	b	5.8
32-20	2.7	4	de	de	8.2	114.3	4	c	b	9.2
17-26	7.9	4	cde	cde	59.7	112.9	4	c	b	13.8
32-14	15.6	4	bc	bc	76.1	46.7	3	d	c	4.3
17-20	12.4	8	c	cd	67.8	12.4	8	e	d	67.8
20-20	8.7	8	cd	cde	65.0	8.7	8	ef	de	65.0
26-14	1.1	4	e	e	200.0	7.3	4	ef	de	51.9
32-11	1.3	7	e	e	197.7	1.3	7	f	e	197.7
26-11	0.0	4	e	e	--	0.0	4	f	e	--
20-14	0.0	4	e	e	--	0.0	4	f	e	--
17-14	0.0	3	e	e	--	0.0	4	f	e	--
20-11	0.0	4	e	e	--	0.0	4	f	e	--
17-11	0.0	4	e	e	--	0.0	4	f	e	--
Mature Pod Dry Weight Percentage (%)										
20-26	13.4	4	cd	bc	40.4	93.1	3	a	a	2.0
17-20	93.0	8	a	a	9.9	93.0	8	a	a	9.9
32-26	43.4	4	b	b	23.1	91.3	4	a	a	1.3
26-20	30.9	4	bc	bc	18.8	90.1	4	a	a	4.4
32-20	6.7	4	cd	c	21.5	86.8	4	a	ab	4.4
20-20	86.7	8	a	a	14.8	86.7	8	a	ab	14.8
17-26	15.6	4	cd	bc	63.2	86.6	4	a	ab	5.0
26-26	12.9	3	cd	bc	106.1	83.1	4	a	ab	9.9
32-14	29.4	4	bc	bc	73.7	79.3	3	ab	ab	2.5
26-14	6.7	4	cd	c	200.0	56.9	4	b	b	35.0
32-11	20.7	7	cd	bc	160.7	20.7	7	c	c	160.7
20-14	--	-	--	--	--	0.0	1	c	c	--
26-11	0.0	4	d	c	--	0.0	2	c	c	--

[†]Treatments with different letters are significantly different.
 Largest values designated by "a".

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Table B-6. Total pod number and mature pod number treatment means, number of plants, coefficient of variability, and mean separation by Duncan's Multiple Range Test for all treatments.

Temp. Treat.	Second Harvest[†]					Final Harvest[†]				
	Mean	N	alpha .05	.01	C.V.	Mean	N	alpha .05	.01	C.V.
					Total Pod Number (No.)					
17-26	354.5	4	a	a	3.1	487.8	4	a	a	11.9
20-26	282.5	4	b	b	10.7	403.3	3	b	b	9.7
26-26	242.3	3	c	c	15.7	290.8	4	c	c	11.1
32-26	223.5	4	c	c	14.0	261.8	4	d	cd	7.2
26-20	228.8	4	c	c	12.8	235.5	4	d	de	8.7
32-20	164.8	4	d	d	3.7	205.3	4	e	e	4.5
32-14	143.5	4	d	d	20.1	201.3	3	e	e	17.6
26-14	31.3	4	e	e	32.1	30.3	4	f	f	18.0
32-11	24.9	7	ef	e	54.0	24.9	7	f	f	54.0
17-20	13.4	8	efg	e	60.5	13.4	8	f	f	60.5
20-20	10.8	8	efg	e	73.0	10.8	8	f	f	73.0
20-14	0.0	4	g	e	--	0.5	4	f	f	200.0
26-11	2.5	4	fg	e	40.0	0.5	4	f	f	115.5
17-14	0.0	3	g	e	--	0.0	4	f	f	--
20-11	0.0	4	g	e	--	0.0	4	f	f	--
17-11	0.0	4	g	e	--	0.0	4	f	f	
					Mature Pod Number (No.)					
32-26	22.5	4	a	a	34.3	124.3	4	a	a	4.9
26-20	21.3	4	a	a	23.5	121.5	4	a	a	10.1
20-26	6.0	4	cd	cd	36.0	97.7	3	b	b	7.0
32-20	3.0	4	d	cd	0.0	90.8	4	b	bc	11.4
17-26	7.0	4	cd	cd	64.9	80.8	4	c	cd	10.9
26-26	6.0	3	cd	cd	116.7	75.0	4	cd	d	5.4
32-14	17.0	4	ab	ab	79.4	69.0	3	d	d	5.2
17-20	11.5	8	bc	bc	66.9	11.5	8	e	e	66.9
26-14	1.3	4	d	d	200.0	9.8	4	ef	ef	46.9
20-20	7.1	8	cd	cd	66.4	7.1	8	efg	ef	66.4
32-11	2.7	7	d	d	191.1	2.7	7	fg	ef	191.1
26-11	0.0	4	d	d	--	0.0	4	g	f	--
20-14	0.0	4	d	d	--	0.0	4	g	f	--
17-14	0.0	3	d	d	--	0.0	4	g	f	--
20-11	0.0	4	d	d	--	0.0	4	g	f	--
17-11	0.0	4	d	d	--	0.0	4	g	f	--

[†]Treatments with different letters are significantly different. Largest values designated by "a".

Table B-7. Mature pod number percentage and reproductive dry weight percentage treatment means, number of plants, coefficient of variability, and mean separation by Duncan's Multiple Range Test for all treatments.

Temp. Treat.	Second Harvest[†]					Final Harvest[†]				
	Mean	N	.05	.01	C.V.	Mean	N	.05	.01	C.V.
Mature Pod Number Percentage (%)										
17-20	81.5	8	a	a	16.4	81.5	8	a	a	16.4
20-20	72.2	8	a	a	28.0	72.2	8	a	ab	28.0
26-20	9.5	4	b	b	28.9	52.0	4	b	bc	15.7
32-26	10.2	4	b	b	39.8	47.6	4	bc	c	8.1
32-20	1.8	4	b	b	3.8	44.4	4	bc	cd	14.0
32-14	10.9	4	b	b	81.3	34.9	3	bcd	cde	15.1
26-14	2.8	4	b	b	200.0	32.4	4	bcd	cde	50.1
26-26	2.3	3	b	b	104.4	26.0	4	cde	cde	12.0
20-26	2.1	4	b	b	33.1	24.5	3	cde	cde	16.2
17-26	2.0	4	b	b	67.3	16.7	4	de	de	15.1
32-11	13.5	7	b	b	162.9	13.5	7	de	e	162.9
20-14	--	-	-	-	--	0.0	1	de	e	--
26-11	0.0	4	b	b	--	0.0	2	e	e	--
Total Reproductive Weight Percentage (%)										
26-26	37.7	3	b	ab	10.7	59.8	4	a	a	3.2
32-20	33.5	4	b	b	6.1	58.8	4	a	a	2.0
26-20	44.5	4	a	a	16.8	58.1	4	a	a	2.8
20-26	37.6	4	b	ab	10.4	56.2	3	ab	ab	3.5
32-26	35.0	4	b	b	2.9	52.3	4	b	bc	1.5
17-26	36.7	4	b	b	7.8	47.7	4	c	c	3.9
32-14	35.0	4	b	b	16.0	36.7	3	d	d	7.4
32-11	10.6	7	c	c	68.1	10.6	7	e	e	68.1
26-14	6.2	4	cd	cd	33.3	5.5	4	f	f	17.1
20-20	3.8	8	de	d	73.4	3.8	8	fg	f	73.4
17-20	3.6	8	de	d	63.8	3.6	8	fg	f	63.8
20-14	0.0	4	e	d	--	0.3	4	g	f	200.0
26-11	0.6	4	de	d	55.9	0.1	4	g	f	154.1
17-14	0.0	3	e	d	--	0.0	4	g	f	--
20-11	0.0	4	e	d	--	0.0	4	g	f	--
17-11	0.0	4	e	d	--	0.0	4	g	f	--

† Treatments with different letters are significantly different. Largest values designated by "a".

APPENDIX C

TABLES OF SEPARATE NIGHT OR DAY
TEMPERATURE ANALYSIS OF VARIANCE SIGNIFICANCE
AND R^2 FOR ALL VARIABLES

Table C-1. Separate day temperature analysis of variance significance and R^2 for all variables of the second harvest.

| Variable | Day Temperature (C) | | | | | | | |
| | 17 | | 20 | | 26 | | 32 | |
	P>F	R^2	P>F	R^2	P>F	R^2	P>F	R^2
Total dry weight	.0001	.99	.0001	.98	.0001	.97	.0001	.89
Root dry weight	.0001	.99	.0001	.99	.0001	.90	.0005	.68
Root dry weight percentage	.0001	.96	.0001	.95	.0001	.95	.0001	.85
Stem dry weight	.0001	.99	.0001	.97	.0001	.93	.0001	.82
Stem dry weight percentage	.0001	.96	.0001	.95	.0001	.93	.0165	.48
Leaf dry weight	.0001	.98	.0001	.93	.0001	.93	.0001	.79
Leaf dry weight percentage	.0524	.39	.0279	.42	.0001	.97	.0001	.86
Total pod dry weight	.0001	.91	.0001	.95	.0001	.97	.0001	.86
Mature pod dry weight	.0120	.51	.0026	.57	.0001	.86	.0002	.77
Mature pod dry weight percentage	.0001	.95	.0001	.92	.0048	.68	.2046	.26
Total pod number	.0001	1.00	.0001	.99	.0001	.97	.0001	.95
Mature pod number	.0115	.51	.0033	.57	.0001	.86	.0024	.61
Mature pod number percentage	.0001	.93	.0001	.82	.0128	.61	.6507	.10
Total reproductive weight percentage	.0001	.98	.0001	.98	.0001	.96	.0001	.86

Table C-2. Separate night temperature analysis of variance significance and R^2 for all variables of the second harvest.

Variable	Night Temperature (C)							
	11		14		20		26	
	P>F	R^2	P>F	R^2	P>F	R^2	P>F	R^2
Total dry weight	.0001	.97	.0001	.98	.0001	.95	.0237	.56
Root dry weight	.0001	.95	.0001	.97	.0001	.97	.0023	.72
Root dry weight percentage	.0001	.94	.0001	.95	.0001	.93	.0493	.50
Stem dry weight	.0001	.95	.0001	.99	.0001	.94	.0559	.48
Stem dry weight percentage	.0022	.61	.0001	.90	.0001	.94	.0964	.42
Leaf dry weight	.0001	.97	.0001	.99	.0001	.89	.0292	.54
Leaf dry weight percentage	.0001	.75	.0026	.71	.0001	.75	.0925	.43
Total pod dry weight	.0081	.53	.0001	.90	.0001	.94	.3199	.26
Mature pod dry weight	.4446	.16	.0133	.61	.0002	.61	.0040	.69
Mature pod dry weight percentage	.2549	.14	.1244	.35	.0001	.93	.0029	.71
Total pod number	.0003	.70	.0001	.95	.0001	.98	.0002	.81
Mature pod number	.4162	.17	.0173	.59	.0010	.55	.0045	.68
Mature pod number percentage	.2610	.14	.1713	.29	.0001	.87	.0015	.74
Total reproductive weight percentage	.0025	.61	.0001	.97	.0001	.96	.6222	.14

Table C-3. Separate day temperature analysis of variance significance and R^2 for all variables of the final harvest.

Variable	Day Temperature (C)							
	17		20		26		32	
	P>F	R^2	P>F	R^2	P>F	R^2	P>F	R^2
Total dry weight	.0001	.98	.0001	.98	.0001	.96	.0001	.98
Root dry weight	.0001	.99	.0001	.99	.0001	.94	.0192	.50
Root dry weight percentage	.0001	.99	.0001	.97	.0001	.95	.0001	.92
Stem dry weight	.0001	.99	.0001	.97	.0001	.98	.0001	.90
Stem dry weight percentage	.0001	.97	.0001	.97	.0001	.99	.0001	.90
Leaf dry weight	.0001	.98	.0001	.93	.0001	.93	.0001	.92
Leaf dry weight percentage	.0001	.88	.0001	.81	.0001	.98	.0001	.95
Mature pod dry weight	.0001	.98	.0001	.99	.0001	.99	.0001	.99
Total pod dry weight	.0001	.97	.0001	.99	.0001	.99	.0001	.99
Mature pod dry weight percentage	.2255	.14	.0001	.86	.0001	.90	.0002	.74
Total pod number	.0001	.99	.0001	.99	.0001	.98	.0001	.97
Mature pod number	.0001	.97	.0001	.99	.0001	.99	.0001	.99
Mature pod number percentage	.0001	.90	.0024	.74	.0011	.79	.0075	.56
Total reproductive weight percentage	.0001	.99	.0001	.99	.0001	1.00	.0001	.96

Table C-4. Separate night temperature analysis of variance significance and R² for all variables of the final harvest.

Variable	Night Temperature (C)							
	11		14		20		26	
	P>F	R²	P>F	R²	P>F	R²	P>F	R²
Total dry weight	.0001	.96	.0001	.98	.0001	.87	.0535	.49
Root dry weight	.0001	.93	.0001	.95	.0001	.98	.0199	.58
Root dry weight percentage	.0001	.94	.0001	.99	.0001	.98	.4742	.20
Stem dry weight	.0001	.95	.0001	.99	.0001	.96	.0008	.77
Stem dry weight percentage	.0010	.65	.0001	.97	.0001	.98	.0001	.87
Leaf dry weight	.0001	.96	.0001	.99	.0001	.90	.0956	.43
Leaf dry weight percentage	.0002	.72	.0001	.86	.0001	.90	.2968	.28
Mature pod dry weight	.0073	.54	.0001	.99	.0001	.99	.0141	.60
Total pod dry weight	.4446	.16	.0001	.99	.0001	.98	.0028	.71
Mature pod dry weight percentage	.4295	.09	.0185	.80	.5698	.09	.0737	.45
Total pod number	.0002	.71	.0001	.97	.0001	.99	.0001	.88
Mature pod number	.4162	.17	.0001	.99	.0001	.97	.0001	.92
Mature pod number percentage	.4356	.09	.1445	.54	.0017	.52	.0001	.94
Total reproductive weight percentage	.0021	.61	.0001	.99	.0001	.99	.0001	.91

APPENDIX D

TABLES OF TREATMENT MEANS, NUMBER OF
PLANTS, AND MEAN SEPARATION BY DUNCAN'S MULTIPLE
RANGE TEST FOR EITHER DAY OR NIGHT TEMPERATURE

Table D-1. Total dry weight, root dry weight, root dry weight percentage, stem dry weight, stem dry weight percentage, leaf dry weight, leaf dry weight percentage treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for day temperature.

Tempera-ture (C)	Second Harvest[†]				Final Harvest[†]			
			alpha				alpha	
	Mean	N	.05	.01	Mean	N	.05	.01
Total Dry Weight (gm)								
17	199.0	19	a	a	218.0	20	a	a
20	163.8	20	b	b	187.9	19	b	b
26	171.1	15	b	b	226.0	16	a	a
32	131.6	19	c	c	188.2	18	b	b
Root Dry Weight (gm)								
17	28.2	19	a	a	28.4	20	a	a
20	24.8	20	b	b	26.1	19	b	b
26	18.4	15	c	c	20.1	16	c	c
32	13.5	19	d	d	14.0	18	d	d
Root Dry Weight Percentage (%)								
17	20.5	19	a	a	20.9	20	a	a
20	20.8	20	a	a	19.3	19	b	b
26	11.4	15	b	b	10.4	16	c	c
32	11.0	19	b	b	9.5	18	c	c
Stem Dry Weight (gm)								
17	88.2	19	a	a	91.1	20	a	a
20	70.9	20	b	b	76.3	19	b	b
26	60.9	15	c	c	67.5	16	c	c
32	42.2	19	d	d	46.7	18	d	d
Stem Dry Weight Percentage (%)								
17	39.4	19	a	a	39.1	20	a	a
20	39.0	20	a	a	39.1	19	a	a
26	36.5	15	b	b	32.4	16	b	b
32	32.9	19	c	c	28.1	18	c	c
Leaf Dry Weight (gm)								
17	61.8	19	a	a	61.1	20	a	a
20	48.2	20	b	b	51.4	19	b	b
26	49.6	15	b	b	53.3	16	b	b
32	37.2	19	c	c	42.8	18	c	c
Leaf Dry Weight Percentage (%)								
17	30.5	19	a	a	28.2	20	b	ab
20	30.4	20	a	a	29.7	19	a	a
26	30.8	15	a	a	26.1	16	c	c
32	30.0	19	a	a	26.7	18	c	bc

[†]Means with different letters are significantly different. Largest values designated by "a".

Table D-2. Total pod dry weight, mature pod dry weight, mature pod
dry weight percentage, total pod number, mature pod number,
mature pod number percentage, total reproductive weight
percentage treatment means, number of plants, and mean
separation by Duncan's Multiple Range Test for day temperature.

Tempera-	Second Harvest [+]		alpha		Final Harvest [+]		alpha	
ture (C)	Mean	N	.05	.01	Mean	N	.05	.01
Total Pod Dry Weight (gm)								
17	16.3	19	b	b	31.2	20	b	b
20	15.3	20	b	b	29.5	19	b	b
26	35.7	15	a	a	79.6	16	a	a
32	32.8	19	a	a	77.5	18	a	a
Mature Pod Dry Weight (gm)								
17	6.9	19	ab	a	27.5	20	b	b
20	4.9	20	b	a	27.1	19	b	b
26	9.0	15	a	a	68.0	16	a	a
32	9.1	19	a	a	65.8	18	a	a
Mature Pod Dry Weight Percentage (%)								
17	67.2	12	a	a	90.9	12	a	a
20	62.3	12	a	a	81.1	12	a	ab
26	12.6	15	c	b	65.7	14	b	bc
32	24.4	19	b	b	60.9	18	b	c
Total Pod Number (No.)								
17	80.3	19	b	b	102.9	20	b	b
20	60.8	20	c	c	68.3	19	c	c
26	118.5	15	a	a	139.3	16	a	a
32	121.1	19	a	a	147.0	18	a	a
Mature Pod Number (No.)								
17	6.3	19	ab	ab	20.8	20	c	c
20	4.1	20	b	b	18.4	19	c	c
26	7.2	15	ab	ab	51.6	16	b	b
32	9.9	19	a	a	60.3	18	a	a
Mature Pod Number Percentage (%)								
17	55.0	12	a	a	59.9	12	a	a
20	48.8	12	a	a	54.3	12	a	a
26	3.7	15	b	b	31.6	14	b	b
32	9.8	19	b	b	31.5	18	b	b
Total Reproductive Weight Percentage (%)								
17	9.2	19	c	c	11.0	20	c	c
20	9.0	20	c	c	10.5	19	c	c
26	21.2	15	b	b	30.9	16	b	b
32	25.7	19	a	a	34.9	18	a	a

[+] Means with different letters are significantly different. Largest
values designated by "a".

Table D-3. Total dry weight, root dry weight, root dry weight percentage, stem dry weight, stem dry weight percentage, leaf dry weight, leaf dry weight percentage treatment means, number of plants, and mean separation by Duncan's Multiple Range Test for night temperature.

Tempera-	Second Harvest [†]				Final Harvest[†]			
			alpha				alpha	
ture (C)	Mean	N	.05	.01	Mean	N	.05	.01
Total Dry Weight (gm)								
11	51.8	19	d	d	56.7	19	a	a
14	107.9	15	c	c	124.1	15	b	b
20	289.6	24	a	a	311.9	24	c	c
26	171.3	15	b	b	300.6	15	c	c
Root Dry Weight (gm)								
11	8.5	19	c	c	10.0	19	a	a
14	12.9	15	b	b	16.8	15	b	b
20	41.5	24	a	a	40.6	24	c	c
26	14.2	15	b	b	14.8	15	d	d
Root Dry Weight Percentage (%)								
11	23.0	19	a	a	23.1	19	a	a
14	19.6	15	b	b	20.5	15	b	b
20	13.8	24	c	c	12.3	24	c	c
26	8.2	15	d	d	4.9	15	d	d
Stem Dry Weight (gm)								
11	20.1	19	c	c	21.9	19	d	d
14	43.4	15	b	b	51.8	15	c	c
20	127.2	24	a	a	125.4	24	a	a
26	48.4	15	b	b	65.9	15	b	b
Stem Dry Weight Percentage (%)								
11	37.3	19	b	b	37.3	19	b	a
14	37.8	15	b	b	39.1	15	a	a
20	41.7	24	a	a	38.5	24	ab	a
26	28.2	15	c	c	21.8	15	c	b
Leaf Dry Weight (gm)								
11	19.4	19	d	d	20.9	19	d	d
14	34.1	15	c	c	37.1	15	c	c
20	46.0	24	a	a	84.0	24	a	a
26	84.0	15	b	b	56.8	15	b	b
Leaf Dry Weight Percentage (%)								
11	35.2	19	a	a	35.0	19	a	a
14	31.6	15	b	b	30.3	15	b	b
20	28.1	24	c	c	26.0	24	c	c
26	26.9	15	c	c	18.7	15	d	d

[†] Means with different letters are significantly different. Largest values designated by "a".

Table D-4. Total pod dry weight, mature pod dry weight, mature pod dry
weight percentage, total pod number, mature pod number,
mature pod number percentage, total reproductive weight
percentage treatment means, number of plants and mean sepa-
ration by Duncan's Multiple Range Test for night temperature.

Tempera-	Second Harvest[†]		alpha		Final Harvest[†]		alpha	
ture (C)	Mean	N	.05	.01	Mean	N	.05	.01
Total Pod Dry Weight (gm)								
11	3.3	19	a	a	3.2	19	d	d
14	15.7	15	b	b	15.1	15	c	c
20	29.3	24	c	c	55.4	24	b	b
26	51.4	15	d	d	149.0	15	a	a
Mature Pod Dry Weight (gm)								
11	0.5	19	c	b	0.5	19	a	a
14	4.5	15	b	b	11.3	15	b	b
20	12.1	24	a	a	49.4	24	c	c
26	11.5	15	a	a	131.6	15	d	d
Mature Pod Dry Weight Percentage (%)								
11	13.1	11	b	b	16.1	9	c	c
14	18.0	8	b	b	58.2	8	b	b
20	66.2	24	a	a	89.4	24	a	a
26	21.9	15	b	b	88.2	15	a	a
Total Pod Number (No.)								
11	9.7	19	d	d	9.3	19	d	d
14	46.6	15	c	c	48.5	15	c	c
20	73.6	24	b	b	81.5	24	b	b
26	277.9	15	a	a	358.1	15	a	a
Mature Pod Number (No.)								
11	1.0	19	c	b	1.0	19	d	d
14	4.9	15	b	b	16.4	15	c	c
20	10.3	24	a	a	41.6	24	b	b
26	10.6	15	a	a	94.2	15	a	a
Mature Pod Number Percentage (%)								
11	8.6	11	b	b	10.5	9	c	b
14	6.8	8	b	b	29.3	8	b	b
20	53.1	24	a	a	67.3	24	a	a
26	4.3	15	b	b	29.0	15	b	b
Total Reproductive Weight Percentage (%)								
11	4.0	19	d	d	3.9	19	d	d
14	11.0	15	c	c	8.9	15	c	c
20	15.5	24	b	b	22.0	24	b	b
26	36.7	15	a	a	53.8	15	a	a

† Means with different letters are significantly different.
Largest values designated by "a".

APPENDIX E

TABLES OF ANALYSIS OF VARIANCE F-VALUES,
R^2, AND PARTIAL SUM OF SQUARES SIGNIFICANCE FOR ALL
VARIABLES OF THE SECOND OR FINAL HARVEST

Table E-1. Analysis of variance F-value, R^2, and partial sum of squares significance for all variables of the final harvest.

Variable	Day Temperature		Night Temperature		Day x Night Interaction		R^2
	F-value	P>F	F-value	P>F	F-value	P>F	
Total dry weight	34.4	.0001	807.5	.0001	66.4	.0001	.98
Root dry weight	30.5	.0001	473.4	.0001	183.9	.0001	.99
Root dry weight percentage	347.2	.0001	584.0	.0001	51.1	.0001	.98
Stem dry weight	14.4	.0001	284.6	.0001	142.8	.0001	.98
Stem dry weight percentage	87.1	.0001	224.7	.0001	127.0	.0001	.98
Leaf dry weight	5.2	.0032	156.1	.0001	65.5	.0001	.96
Leaf dry weight percentage	12.4	.0001	164.2	.0001	29.0	.0001	.93
Total pod dry weight	224.2	.0001	1316.2	.0001	119.4	.0001	.99
Mature pod dry weight	149.8	.0001	1050.8	.0001	101.8	.0001	.99
Mature pod dry weight percentage	4.6	.0070	48.6	.0001	3.2	.0102	.82
Total pod number	34.3	.0001	921.3	.0001	106.8	.0001	.99
Mature pod number	243.9	.0001	767.9	.0001	118.1	.0001	.99
Mature pod number percentage	1.4	.2530	31.5	.0001	6.3	.0001	.81
Total reproductive weight percentage	342.3	.0001	1030.0	.0001	132.3	.0001	.99

Table E-2. Analysis of variance F-value, R^2, and partial sum of squares significance for all variables of the second harvest.

Variable	Day Temperature		Night Temperature		Day x Night Interaction		R^2
	F-value	P>F	F-value	P>F	F-value	P>F	
Total dry weight	18.1	.0001	714.3	.0001	122.2	.0001	.99
Root dry weight	27.0	.0001	694.5	.0001	172.6	.0001	.93
Root dry weight percentage	202.1	.0001	240.9	.0001	40.2	.0001	.96
Stem dry weight	10.1	.0001	341.9	.0001	118.0	.0001	.98
Stem dry weight percentage	12.5	.0001	55.9	.0001	46.2	.0001	.93
Leaf dry weight	7.7	.0002	200.1	.0001	73.5	.0001	.97
Leaf dry weight percentage	2.9	.0421	47.4	.0001	16.3	.0001	.84
Total pod dry weight	46.6	.0001	159.4	.0001	36.3	.0001	.94
Mature pod dry weight	5.7	.0019	21.2	.0001	8.5	.0001	.74
Mature pod dry weight percentage	11.1	.0001	14.4	.0001	15.9	.0001	.85
Total pod number	56.3	.0001	764.4	.0001	84.2	.0001	.98
Mature pod number	7.3	.0004	13.9	.0001	6.5	.0001	.67
Mature pod number percentage	20.8	.0001	24.9	.0001	16.3	.0001	.89
Total reproductive weight percentage	104.3	.0001	249.6	.0001	43.3	.0001	.96

APPENDIX F

VEGETATIVE AND REPRODUCTIVE
PLANT COMPONENT RAW DATA

Table F-1. Legend for computer coded variable names.

OBS	=	Number of observations
DTEMP	=	Day temperature (C)
NTEMP	=	Night temperature (C)
ROOT_WT	=	Root dry weight (gm)
STEM_WT	=	Stem dry weight (gm)
TOT_LEAF	=	Leaf dry weight (gm)
T_DRY_WT	=	Total dry weight (gm)
POD_5_NO	=	Mature pod number (No.)
TOT_P_NO	=	Total pod number (No.)
POD_5_WT	=	Mature pod dry weight (gm)
T_POD_WT	=	Total pod dry weight (gm)
POD_5_NP	=	Mature pod number percentage (%)
POD_5_TP	=	Mature pod weight percentage (%)
STEM_P	=	Stem dry weight percentage (%)
ROOT_P	=	Root dry weight percentage (%)
T_LEAF_P	=	Leaf dry weight percentage (%)
TPP_WT_P	=	Reproductive dry weight percentage (%)

Table F-2. Vegetative and reproductive plant component raw data of the second harvest.

T DRP WT LB	T LEAF LB	ROOT LB	STEM LB	POD S TP	POD S NP	T PCD WT LB	PCD S WT LB	TOT P ZO	POD S ZO	T DRY WT	TOT LEAF	STEM WT	ROOT WT	NTEM	PTEM	OBS
0.00	27.31	39.93	32.86	.	.	0.00	0.00	0	0	7.03	1.92	2.31	2.87	11	17	1
0.00	33.97	29.37	36.93	.	.	0.00	0.00	0	0	8.07	2.72	2.93	2.37	11	17	2
0.00	27.32	29.86	36.44	.	.	0.00	0.00	0	0	8.23	2.74	2.79	2.60	11	17	3
0.00	30.18	33.44	36.25	.	.	0.00	0.00	0	0	7.26	2.12	2.51	2.60	11	17	4
0.00	31.18	29.24	37.24	.	.	0.00	0.00	0	0	15.56	4.70	5.75	5.16	14	17	5
0.00	30.47	29.34	39.01	.	.	0.00	0.00	0	0	14.56	4.09	6.27	5.85	14	17	6
0.00	28.75	15.89	48.47	.	.	0.00	0.00	0	0	16.99	4.04	6.02	6.37	14	17	7
0.00	30.89	15.45	49.18	.	.	0.00	0.00	0	0	14.80	4.09	4.53	5.28	20	20	8
4.43	50.47	15.63	50.75	97.56	92.86	15.55	15.02	14	13	17.67	1.85	6.56	5.88	20	20	9
4.89	50.55	15.03	49.05	97.22	85.73	18.44	18.04	20	17	28.67	0.85	6.12	5.38	20	20	10
3.65	33.45	16.33	43.84	96.38	78.71	1.93	1.50	2	3	21.48	1.80	6.44	5.71	20	20	11
1.21	31.63	15.35	41.71	97.62	67.64	6.90	6.57	8	7	17.61	1.71	4.87	4.01	20	20	12
5.21	30.58	8.25	29.67	98.32	89.03	0.53	4.50	5	5	35.81	3.61	9.70	1.84	26	20	13
2.91	27.67	6.73	25.80	98.11	94.12	1.71	4.57	4	4	29.54	3.46	6.67	3.32	26	20	14
5.64	30.46	8.28	26.04	10.71	1.86	0.42	4.12	2	2	37.55	3.44	7.97	3.00	26	20	15
4.46	31.95	32.24	37.14	29.49	1.03	0.00	0.00	0	0	31.64	3.94	5.53	4.04	11	17	16
7.94	36.00	35.71	35.71	15.41	2.17	0.00	0.00	0	0	28.52	2.94	7.05	4.08	11	17	17
7.94	30.54	37.35	35.15	.	.	0.00	0.00	0	0	33.74	3.46	9.70	8.31	11	17	18
0.00	31.29	37.30	35.33	.	.	0.00	0.00	0	0	23.65	6.95	7.07	7.91	14	17	19
0.00	34.16	39.28	34.01	.	.	0.00	0.00	0	0	35.15	12.84	6.70	6.23	14	17	20
0.00	21.93	15.28	50.77	99.00	75.00	3.93	3.93	4	4	28.11	10.12	11.75	4.31	20	20	21
0.00	20.93	15.51	50.77	89.00	100.00	4.75	4.42	10	8	33.22	10.84	12.40	5.07	20	20	22
0.00	30.30	16.65	43.08	86.15	64.29	11.93	11.83	12	11	33.00	12.12	9.57	5.00	20	20	23
0.00	30.38	16.08	48.68	76.60	58.00	10.63	5.14	8	7	31.99	9.90	13.71	4.47	20	20	24
0.00	30.08	16.11	48.05	72.40	51.00	0.70	0.70	7	4	35.57	9.83	11.87	5.71	20	20	25
1.04	26.40	17.61	40.66	19.98	2.90	4.85	7.56	6	6	21.40	8.80	11.26	4.02	20	20	26
4.39	28.76	17.26	25.77	19.45	2.17	6....	9.56	23	9	32.56	9.44	9.70	4.63	26	20	37
9.94	27.14	9.52	25.77	6.86	1.20	56.52	3.88	276	249	18.65	10.65	56.43	17.23	26	20	38

Table F-2 - Continued.

T PP WT P	T LEAF P	ROOT P	STEM P	PCO S TP	PCO S NP	T ROO WT	ROO S WT	TOT P NO	ROO S NO	T DRY WT	TOT LEAF	STEM WT	ROOT WT	N TEMP	D TEMP	OBS
														26	26	39
														11	26	40
														11	26	41
														11	26	42
														14	26	43
														14	26	44
														14	26	45
														20	26	46
														20	26	47
														20	26	48
														26	26	49
														26	26	50
														11	32	51
														11	32	52
														11	32	53
														14	32	54
														14	32	55
														14	32	56
														14	32	57
														20	32	58
														20	32	59
														20	32	60
														26	32	61
														26	32	62
														11	32	63
														14	32	64
														14	32	65
														14	32	66
														20	32	67
														20	32	68
														20	32	69
														26	32	70
														26	32	71
														26	32	72
														26	32	73

Table F-3. Vegetative and reproductive plant component raw data of the final harvest.

OBS	DTEMP	NTEMP	ROOT WT	STEM WT	TOT LEAF WT	TOP WT	T DRY WT	POD 5 NO	TOT NO	T POD NO	POD 5 WT	TOT P WT	POD 5 NC	TOT P NC	POD 5 NP	POD 5 TP	STEM R	ROOT R	T LEAF R	T PP WT R
1	17	11	5.03	5.13	3.88	14.04											36.54	35.83	27.64	0.00
2	17	11	5.34	4.28	2.41	12.03											36.80	31.91	31.29	0.00
3	17	11	3.86	3.24	3.69	10.79											35.80	32.63	31.57	0.00
4	17	11	4.18	4.76	3.42	12.36											35.31	35.10	29.59	0.00
5	17	14	4.59	7.33	3.56	15.48											35.35	36.48	32.21	0.00
6	17	14	7.57	7.03	7.85	22.45											35.85	36.01	30.57	0.00
7	17	14	6.19	6.55	5.85	18.59											38.20	38.32	26.74	0.00
8	17	20	4.43	6.37	5.85	16.66											40.18	15.99	28.47	0.43
9	17	20	5.80	6.37	5.07	17.24	0.55	7.26	86.0	97.6	4.09	0.00	15.55	15.90	28.64	5.41
10	20	20	6.37	6.65	4.08	17.10	0.48	9.72	77.0	95.4	2.09	0.09	18.82	33.04	33.42	2.03
11	20	20	6.35	5.37	7.38	19.10	4.93	9.72	67.0	96.3	4.05	0.08	15.91	27.81	33.12	1.65
12	20	20	5.20	4.04	4.68	13.92	0.72	20.56	14.0	81.0	5.05	0.16	15.74	27.67	33.51	1.21
13	20	20	5.48	6.01	3.60	15.09	9.48	135.84	89.0	75.38	3.07	0.05	12.92	24.63	20.49	1.57
14	20	20	6.31	18.05	60.67	84.81	9.72	108.24	98.2	98.32	4.93	1.05	16.74	23.81	16.01	6.47
15	26	26	6.34	5.96	44.63	298.30	11.40	149.00	94.0	88.11	7.75	7.40	4.98	15.69	32.47	48.55
16	26	26	6.14	5.44	44.38	282.02	11.63		18.0	80.11	11.63	17.63	6.92	16.57	32.85	46.04
17	26	26	4.78	4.50	5.07	17.10									40.79	17.81	30.79	0.00
18	26	26	4.01	6.50	5.64	15.15									42.07	24.67	33.13	0.00
19	11	11	4.10	6.01	7.01	17.12									25.35	24.61	32.13	0.00
20	11	11	13.51	9.01	6.99	29.63									26.84	15.07	32.64	0.00
21	11	11	13.89	7.06	4.94	26.00									36.84	16.86	32.13	0.00
22	14	14	13.03	9.21	6.87	30.03									34.54	16.02	33.09	0.24
23	14	14	5.93	5.17	5.01	17.01	0.46	6.12	0.00	5.07	38.83	40.05	31.06	1.04
24	14	14	1.31	5.73	5.64	17.63	3.27			5.12	40.05	49.01	31.02	0.35
25	14	14	4.04	5.13	4.50	20.59	4.93		0.29	6.18	50.77	49.08	31.36	0.89
26	17	20	4.47	20.01	17.19	52.33	24.93			161.41	43.44	49.66	31.13	9.94
27	17	20	2.26	19.21	16.89	49.60	17.63			24.02	49.85	50.42	20.42	3.94
28	20	20	6.20	171.27	83.09	319.20	169.60			116.43				2.94
29	20	20	3.15	114.60	82.09	308.53	155.58			140.43				2.01

Table F-3 – Continued.

TPP WT ID	T LEAF ID	ROOT ID	STEM ID	POD L TP	POD L NZ	T POD WT	POD L WT	TOT P NC	POD L NC	T DRY WT	TOT LEAF	STEM WT	ROOT WT	NTEMD	DTEMD	OBS
57.44	18.44	4.92	19.40	92.75	25.00	155.04	144.03	400	100	287.42	52.40	55.77	14.15	26	26	39
0.06	18.15	4.54	45.38	0.00	0	94.00	0.00	1	0	97.42	42.40	44.35	15.86	11	26	40
0.00	30.47	4.63	44.32	·	·	0.06	0.00	7	15	97.85	30.63	31.65	16.30	11	26	41
0.00	36.47	17.63	44.24	0.05	0.06	0.06	0.09	26	7	241.63	116.55	116.55	13.36	14	26	42
0.23	34.65	20.03	45.45	0.35	0.56	0.16	0.23	30	5	271.63	135.56	135.56	16.61	14	26	43
1.14	31.48	11.12	42.24	8.13	31.30	14.29	11.23	37	7	98.27	80.83	60.37	33.30	14	26	44
4.75	31.27	11.68	48.76	6.98	55.07	6.37	6.20	33	106	241.59	80.63	49.97	31.22	20	26	45
6.95	16.48	5.27	49.14	91.40	19.46	8.03	3.68	245	126	272.60	84.69	51.01	20.50	20	26	46
6.11	16.24	4.28	41.16	90.48	31.61	7.23	4.45	205	81	268.85	46.22	100.63	13.65	26	26	47
8.11	16.43	4.45	19.55	90.14	41.14	42.37	1.60	289	74	286.49	84.61	30.95	13.12	26	26	48
3.62	37.03	13.83	17.71	47.14	11.51	10.06	0.00	36	73	277.93	54.62	32.83	13.02	26	26	49
11.29	39.83	15.59	17.42	82.18	25.24	4.28	0.54	3	0	176.30	54.40	30.63	11.98	11	32	50
5.52	38.45	12.02	19.21	74.70	20.32	21.80	1.00	46	4	156.80	50.53	36.21	12.36	11	32	51
5.67	37.00	12.15	31.00	6.44	4	8.99	0.00	31	0	228.61	31.22	25.89	13.80	14	32	52
3.14	37.97	8.74	33.04	7.56	46.46	23.88	7.90	17	65	156.52	34.51	30.95	12.33	14	32	53
0.09	24.97	4.44	30.84	7.10	26.93	21.76	49.45	24	72	176.07	34.54	30.54	13.30	14	32	54
6.63	24.79	4.36	26.85	67.02	51.48	55.90	5.87	27	101	348.12	30.71	41.95	11.13	20	32	55
0.53	16.57	5.99	18.47	80.92	45.46	63.45	9.00	242	94	348.57	30.51	46.63	20.10	20	32	56
2.31	16.65	5.27	22.67	87.84	49.49	141.63	4.96	185	84	228.57	44.28	46.65	20.06	26	32	57
6.29	19.76	6.08	22.78	18.61	49.05	126.65	7.08	208	114	320.85	38.18	46.05	15.15	26	32	58
2.37	19.75	5.06	21.41	90.46	59.62	63.43	45.22	264	129	348.57	41.06	78.05	12.04	26	32	59
11.49		8.85		86.85		147.00	9.10	238	119		63.85	73.15	14.94	11	32	60
36.29				90.90		162.32	137.04	262	130		62.46	62.86	16.90	14	32	61
30.35				92.06		156.84	144.51						17.26	20	32	62

BIOGRAPHICAL SKETCH

Ian Scott Campbell was born October 12, 1948, in Santa Monica, California. He became interested in agriculture at an early age and continued his interest through 4-H activities as a youth. He attended elementary and junior high schools in California and attended Santa Monica High School.

Upon high school graduation in 1966, he attended Los Angeles Pierce Junior College for one year taking basic freshman curricula and basic botany. In 1967 he and his parents moved to Ft. Collins, Colorado, where he enrolled at Colorado State University studying agronomy with an international agronomy minor. In 1971 he received his B. S. degree in agronomy. Immediately he began a Master of Science program researching pasture quality. In August, 1973, he graduated with the M. S. degree. After a year of work and travel, he began studies for the Doctor of Philosophy degree at the University of Florida in September, 1974, with minors in tropical agriculture and human nutrition. The period of study was interrupted with several short periods of nonstudy work.

Upon receiving the Ph.D., he expects to pursue a career in international agriculture. He is a member of Sigma Xi, and Gamma Sigma Delta honor societies as well as the Crop Science Society of America and the American Society of Agronomy.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

D. E. McCloud, Chairman
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

H. Appledorf
Professor of Food Science and
Human Nutrition

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

A. J. Norden
Professor of Agronomy

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

H. L. Popenoe
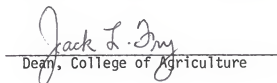Professor of Agronomy, Botany,
Geography, and Soils

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

March 1980

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